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The Place of Telecommunications

Spatial Decision-Making by Firms in the Age of Global Communications

A thesis submitted in conformity with the requirements of Doctor of Philosophy (Ph.D.) in Town & Country Planning.

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I, Jonathan E. Reades confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

The transition to a digital, knowledge-based economy has seemingly thrown the study of industrial spatial strategy into disarray: theory rooted in the analysis of material flows appears insufficient for the study of informational ones. However, this work will argue that many of the basic, historical aspects of firm location identified by the pioneers of spatial analysis remain profoundly relevant today because these enable us to place the modern firm in an appropriate spatial and economic context. We may then combine these fundamental insights with more recent work on infrastructure flexibility, transactions, types of knowledge, and the importance of face-to-face interaction to flesh out a portrait of industrial location in the telecommunications age.

Direct evidence of these strategies in action has been difficult to collect because so many of the inputs to, outputs from, and interactions between firms are invisible. Moreover, traditional social science approaches to data collection and analysis are unable to cope with the flood of information that characterises advanced service economies. The direct study of telecommunications data promises a new and massively scalable way to visualise and explore these crucial connections, but as yet there is little consensus on how to approach such data.

Using very large, but fine-grained data sets from a major British telecommunications company and a large American telecommunications company, and drawing upon the 'eigenplace' methodology developed in collaboration with Francesco Calabrese of the SENSEable City Lab at M.I.T. (Reades et al., 2009; Calabrese et al., 2010), this work explores the extent to which telecommunications flows—in terms of their timing, volume, and geography—can be correlated with firm location and industrial clustering. The finding of industrial 'signatures' in telecommunications data provides evidence of informational strategies at work, and sheds light on the likely future shape of urban and regional economies.

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Data Authorisations & Overview

British Data

Pseudonymous data shared by a major British telecommunications company covering the U.K. (with the notable exception of Hull) for the month of August 2005. Data was provided under the terms of a contractual research agreement between U.C.L. and the British telecommunications company.

American Data

A major American telecommunications company provided aggregate data representing September 2008 telephone calls to and/or from the New York City metro area. Data was provided under the terms of a contractual research agreement between M.I.T. and the American telecommunications company, and were accessed while the author was a visiting researcher at M.I.T.

Population Data (U.K.)

Population figures used in the U.K. analysis were drawn from the 'Mid-2005 Quinary Estimates for CAS wards (experimental)'. These data were selected as they are the closest match for the data supplied by the British telecommunications company (August 2005). They are available for download from the Office for National Statistics (ONS) at: `http://www.statistics.gov.uk/statbase/Product.asp?vlnk=13893` This data is covered by Crown Copyright.

Employment Data (U.K.)

Employment figures used in the U.K. analysis were drawn from the NOMIS Annual Business Inquiry (ABI) employee analysis and accessed under ONS Notice Reference NTC/ABI08-P0496. ABI data is drawn from a 10% sampling of businesses at the CAS Ward level, so I have taken the average sectoral employment for each ward using the five-year time period between 2003 and 2007. The average masks sensitive values and addresses the issue that the sampling methodology may miss an entire sector in a given ward for any given year. In short, each employment value used in the LQ analysis was calculated using the following simple approach: $\sum_{y=2003,2004,2005,2006,2007}^{i} E_i/5$ where E_i is the estimated employment in sector i during year y. This data is covered by Crown Copyright.

Population & Employment Data (U.S.)

The American telecommunications company provided demographic and employment data for New York City wire centres, using the boundary data files to associate each centre with the relevant socioeconomic variables. These figures were reported in aggregate and without the exact boundary, so they cannot be independently tied back to a given Census Block or other statistical unit.

1 Introduction

> We witness today enormous displacements of economic forces, migrations of capital and human labor such as no other age has ever seen. We observe that certain regions rapidly grow poor in human beings and capital, while other become saturated. We see in metropolitan centers great masses conglomerate, seemingly without end.
>
> *Weber, 1909 [1969], p.2*

1.1 Introduction

Over the past forty years, the spread of fixed and mobile telecommunications has radically reshaped the way that we interact with one another and with our urban environments. We now seamlessly and almost unconsciously manoeuvre between a physical 'here' and a digital 'there' on a near-constant basis. And yet, the impact of this change remains poorly understood: not only are the networks themselves entirely invisible, but social science has also been unable to analyse the interactions that these systems enable. Fourteen years after the original publication of *The Rise of the Network Society* (Castells, 1996 [2000]), the 'space of flows' remains largely unmapped (Pain and Hall, 2008, p.1069).

Only recently have telecommunications data begun to be applied in a significant way to the study of human social interaction. Driven by advances in hardware, software, and analytical techniques, researchers have used mobile and fixed-line phone calls, as well as Instant Messaging logs to speculate on 'universal laws' of human friendship and mobility (cf. Gonzàlez et al., 2008; Leskovec and Horvitz, 2008; Onnela et al., 2007). However, managing billions of records spanning Terabytes of disc storage requires the social sciences to adopt entirely new processing and analysis techniques. And while we can expect this emerging 'computational social science' (Lazer et al., 2009) to draw on the natural and computer sciences, which have a longer tradition of coping with 'big data', we must also recognise that a good deal of early research in this field will also, of necessity, be heuristic in nature.

1.2 Context

Although this thesis is focussed on the impact of telecommunications on firm location, we should not—indeed cannot (see Chapter 2 in general and, for instance, page 86 specifically)—ignore the persistence of physical flows: the United States Postal System (2010, p.4) alone processed more than 177 *billion* letters and parcels in 2009, an average of 405,000 million pieces each and every minute. And we should note that this figure does not include the equally substantial flows carried by competitors such as FedEx, UPS, DHL, and CityPost on behalf of businesses. However, although these are staggering volumes of post, a significant trend of the past decade has been the supplanting of physical flows by electronic ones: essentially costless e-mail and voice calls are thought to account for the steady, but surprisingly slow[1], decline in postal volumes—15% for the Royal Mail between 2006 and 2009 (cf. Wearden, 2009), and 10% for air freight carried by Deutsche Post DHL between 2008 and 2009 (2010).

[1] The Universal Postal Union (2010) reports that, following a precipitous decline in volumes in 2008/2009 as a result of the global economic slowdown, mail volumes have 'recovered' to track pre-crisis predictions of a 2% decline *per annum*, with some growth in developing countries offsetting a steeper decline in developed ones.

Telecommunications

In spite of the obviousness of this shift in communications patterns, it can be easy to forget just how radical the change wrought by the introduction of information and communications technology on our day-to-day lives has been, and easier still to forget how quickly all of this change has occurred: in 1880, Britain's first telephone directory listed just 248 subscribers to nineteen exchanges across the country: three in London and sixteen 'in the provinces' (British Telecommunications plc., 2007). By 1905, Britain averaged one line for every hundred households, but since this count included business numbers as well, the number of phones in homes will have been rather lower. Slow but steady growth throughout the first half of the 20th Century brought landlines to 21.6% of households by 1964, followed by a much more rapid rise towards an all-time high of 95% of British households in 1999 (Hamill, 2007).

The uptake of wireless telecommunications, however, makes the landline's adoption rate look stodgy indeed. Britain's first mobile phone call was made on January 1st, 1985 (BBC, 2005b), and its first text message was sent on December 3rd 1992 (BBC Four, 2006). Early handsets cost as much as £3,000, and so it is hardly surprising that ten years after their introduction just 7% of Britons had mobile phones (Wray, 2010). But declining handset and contract costs increased consumer uptake: in 1998 the 'penetration rate' reached 25% and less than a year later it had leaped again to 45% (*ibid.*). In 2002, the Office of Telecommunications (Oftel) was reporting that 75% of UK adults owned a mobile phone (Oftel, 2002), and by 2005 Oftel's successor, the Office of Communications (Ofcom), indicated that the count of active mobile phone subscriptions had actually surpassed the number of men, women, and children in the country. In 2006 the 'penetration rate' topped 116 mobile connections per 100 population (Ofcom, 2007), and Britain was averaging 215 million texts per day (*i. e.* 79 *billion* a year) and growing (BBC Four, 2006).

There has been a similarly large, though less visible, increase in international communication: in 2004 alone, global demand for bandwidth grew by an astonishing 42% (Glasner, 2005). Using data collected

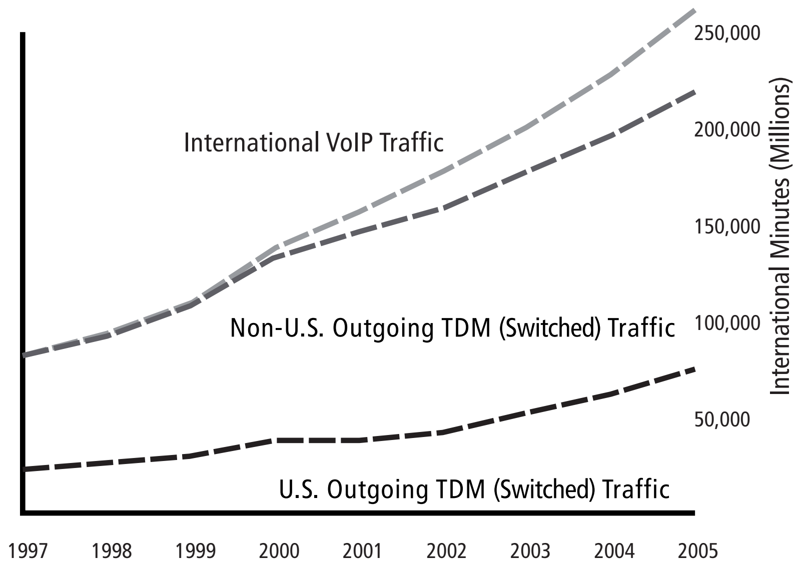


Figure 1.1: Growth in International Calling Minutes (PriMetrica, 2006a; reproduced with permission of TeleGeography/PriMetrica)

via surveys of global network operators, PriMetrica (2006a) reports that, between 1997 and 2005, international Voice over IP (VOIP) traffic rose from 7.5m minutes to 42,602.8m minutes, while total international minutes surpassed a staggering 250 *billion* minutes. Figure 1.1[2]) highlights two dynamics: first, that VOIP growth—which here does not include peer-to-peer systems such as Skype—is rapidly replacing switched (TDM) traffic; and second, that growth in international usage is outpacing growth in America, the traditional pace-setter.

[2] TDM traffic includes all public switched telephone traffic: circuit-switched voice and fax data as well as "international simple resale" (ISR) facilities.

Moreover, it is not simply a case of Europe catching up with North America: rates in Asia, Africa and Latin America have outpaced both regions by as much as 40% (PriMetrica, 2006a)[3]. Clearly, this rise in usage is being fuelled by a fall in price, but the underlying driver seems to be the need, and we might even call it the compulsion, to share information with family, friends, and colleagues. The globalisation of both business and migration—creating what Castells (1996 [2000]) calls the 'space of flows'—seems to require us to stay in touch with people on the other side of the planet much as we would with those who are just down the street. But what does this mean for our notions of community, the nature of employment, the locations of firms, and what do those in turn imply for the future of our cities?

[3] Though this is obviously from a rather lower base

Work & Home

However, we must first place telecommunications in the fuller context of what is happening in the realm of travel. Midas—an auto parts company—recently gave an award for the longest commute in America to someone who travelled 372 miles, three-and-a-half hours in each direction, *every day* (Paumgarten, 2007). The irony of the award is that this modern-day Odysseus works for the network firm Cisco; wasn't the fusion of computers and telecommunications infrastructure supposed to free us from this 'daily grind'? And he is not alone: the number of Americans whose journey to work exceeds 90 minutes in each direction reached 3.5 million in 2006, roughly double the number in 1990, and 17% travel at least 45 minutes in each direction (*ibid.*).

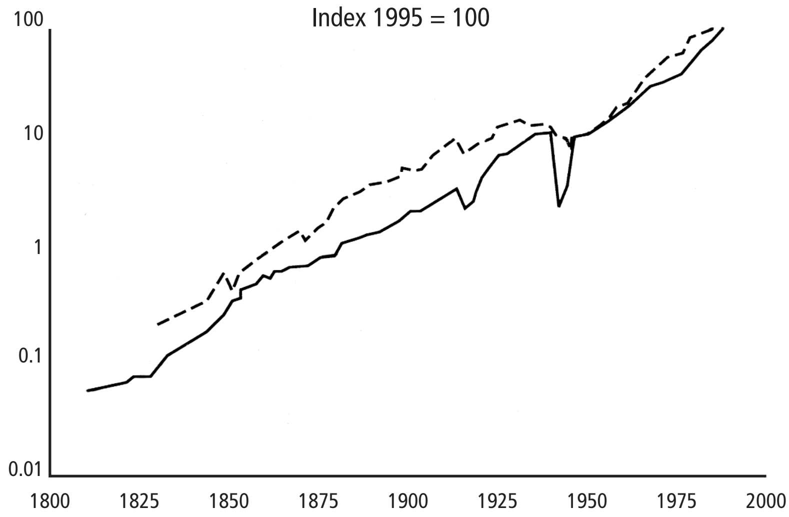


Figure 1.2: Growth of Passenger Transport and Communications in France (Graham and Marvin, 1996, p.262; reproduced with permission of Routledge/Taylor & Francis Group)

Instead, we see travel and communications increasing in near lock-step (see Figure 1.2[4]), a trend that can only make sense if neither is fully capable of meeting our communicational needs: "there is not a simple substitution of the latter for the former, as so often suggested in 'information age' business rhetoric" (Graham, 2002, p.75). Perhaps the use of one even stimulates the use of the other (Hall, 2009, p.811), the link being, as Pain and Hall (2008, p.1068) point out, that we still only really have two ways of moving large amounts of knowledge across long distances efficiently: electronically, and physically inside someone's head. So perhaps this trend is a reflection of the importance of knowledge work, and of knowledge workers to modern economies. In the midst of an 'industrial revolution of data' (Economist, 2010a), those with the capacity to manipulate information and knowledge will be required to do so in a wide range of contexts.

[4] Seemingly because of data availability issues, this spectacular historical data collection exercise has only ever been performed for France; however, the data set underlying this figure has never been properly referenced and so the interpretation should be treated with some care.

What is rather more difficult to grasp is what all of this means for the future of the city. On the one side are those who point to the growth of edge and edgeless cities in American suburbia as a sign of the permanent decline of the traditional urban core and its central business district (CBD); on the other side are those who point to the resurgent growth (and extreme gentrification) of New York, London, and the other global cities as signs that the very largest cities are the command-and-control hubs of an increasingly complex and integrated global economy. My argument is that to understand both of these issues, we need to understand how businesses and individuals select their preferred location from amongst a range of options, and to determine what role telecommunications—and Information and Communications Technology (ICT) in general—play in changing those preferences.

For instance, what is the role of the traditional office when an employee can perform many, and in some cases all, work functions from almost anywhere on the planet? A visit to any coffee shop with

WiFi connectivity will reveal the extent to which contemporary work—preparing presentations, checking email, doing product development—is being transformed by a combination of mobile technologies. However, the lower-than-expected uptake of telecommuting (cf. Mokhtarian, 2003; Jarvis, 2003) suggests a surprising resilience to the 'virtualisation' of the workplace. I will argue that the root cause of this pattern is that some types of exchange, and in particular some types of knowledge exchange, are much less amenable to 'digitisation' than others, and that some sectors are therefore still very much place-bound and very much dependent upon face-to-face interaction.

1.3 Planning for Telecommunications

The Challenge to Theory

We often take it largely as a matter of faith that ICT affects how and why firms choose one site and not another, but it remains somewhat unclear how all of this works from a theoretical standpoint since much of location theory remains 'stuck in the 1st industrial revolution' (Goddard, 1975, p.22). Ultimately, the ability to retrieve, manipulate, and share data from anywhere in the world seems bound to refashion the way that firms use space, but urban studies and planning still seem to be working with models drawn from an earlier era when "the core of [these] analyses were the social, economic, spatial, and environmental aspects of cities dominated by manufacturing and the physical distribution of goods, services, and people" (Graham, 2005, p.104).

In short, "urban telecommunications study has yet to merge into a coherent sub-discipline like transportation did after World War II" (Graham, 1997, p.108). But even were such a sub-discipline to be formed, infrastructure and ICT networks would remain difficult to use in an instrumental fashion since their flexibility and interconnectivity makes the results, at best, unpredictable (Innes, 2005, p.60). So the reality of the city as a 'space of flows' raises serious challenges to which planning—as both a theory of place and a practice of place-making—appears ill-equipped to respond. In effect, although "everything to do with cities in some way involves information flows, communications, transactions, and representations that can be mediated, in part at least, by ICTs" (Graham, 2005, p.104), we nonetheless find that many of the 'policy paradigms' that once applied to the management of infrastructure are largely irrelevant (Graham, 1997, p.109).

The Challenge of Invisibility

Batty identified the basic 'problem' of ICT networks as far back as 1990: "Cities are becoming invisible to us in certain important ways and it seems that this invisibility is increasing at a faster rate than our ability to adapt our research methods to these new circumstances" (1990, p.130). This invisibility is both literal and metaphorical: in operation, telecommunications are invisible and silent; in provision, they are managed by large corporations with customers to protect and competitors to outcompete (Dodge and Kitchin, 2001, p.6). ICT is now so woven into the physical fabric of cities that it is largely overlooked by planners who are much more focussed on systems with obvious externalities (Graham, 2005, pp.99–100). So whereas changes in manufacturing activity or office employment have clear knock-on effects on our day-to-day lives—more trucks on the road, more planes in the sky, more pollution in the air—an increase in informational activity has little obvious impact.

And while researchers can count car journeys, train passengers, or new offices, it has been much harder to do so with informational activity. Most of these electronic flows are across private networks which are not, and never will be, "part of the public domain, and restricted access is a feature of their development..." (Batty, 1990, p.129). In many cases, the data of interest to urban planners may not even have been logged since it is not of interest to network operators, but even where it has been collected there are still multiple, competing operators who will each have a partial view of the total activity in a city or region. And yet, without these data sources it is impossible to build any kind of picture of the local information economy at all.

The Challenge to Analysis

A further challenge is that traditional social science methods appear poorly equipped to cope with the analysis of electronic infrastructure. This is not, of course, to suggest that these methods are no longer useful—in fact, their recombination with new approaches may be particularly powerful (Hall, 2009, p.808)—but that human behaviour is increasingly informed by data retrieved from, or exchanged with, other parts of the world, and that this dynamism is poorly captured by traditional survey or observation techniques (cf. Pain and Hall, 2008, p.1070). The data collected are therefore ill-suited to mapping the informational rhythms of the city and flows of mobility—one conference participant put it this way: "the census only tells me where people sleep" (Anonymous, 2007).

However, thanks to improvements in storage capacity and computing power, Lazer et al. (2009, p.721) argue that we are on the cusp of establishing a 'computational social science' that *is* capable of taking advantage of our ability to collect, analyse, and exploit data of truly breathtaking depth and extent. For instance, the issuer of Visa credit cards recently used a distributed analysis system to process 73 *billion* transactions—36 Terabytes of data—in 13 minutes, radically improving on its previous approach, which had required nearly a month to run to completion (Economist, 2010b). To date, however, computational social science has been "almost exclusively the domain of private companies and government agencies" (Lazer et al., 2009, p.721), and we must find ways to bring this field into the research mainstream where it can become an accepted part of social science academe.

It is now becoming possible to 'see' the city in both space and time with unprecedented resolution and at surprisingly low cost. In place of the hundreds of observers/data collectors needed in the past, commuting data for an entire urban region could be collected by a single researcher with access to the mobile phone network. This transforms utterly the historic dynamics and costs of data collection and thereby transforms the possibilities of evidence-based policy-making and service delivery. Historically, informational flows have been largely impossible to measure except in grand, aggregate ways, but thanks to detailed behavioural data sets we can finally examine both the micro- and macro-scales of human society at once, and begin to explore the interactions between the two (Lazer et al., 2009, p.721).

The Challenge to Concepts of Time & Place

At the end of the 17th Century, the average Dutchman travelled just 40km/year, today they manage that in a day (Bertolini and Dijst, 2003, p.28). So whereas the dense medieval and early-modern city "allowed time constraints to be overcome by minimising distance constraints" (*ibid.*), today's infrastructure provide an alternative solution since they "help to overcome distance constraints by minimising time constraints" (*ibid.*). But in many ways telecommunications goes beyond mere 'minimisation', to 'annihilation', and Graham (1997, p.117) argues that ICT actually constitutes a 'third dimension' of planning: space, time, and now real-time.

The ability to reorganise activities around these dimensions is leading to increasingly complex economic structures: where once the majority of highly-skilled positions were concentrated in London, today there is strong and sustained growth across the Greater South East of England (GSE) in knowledge-intensive sectors, most notably the rise of a high-tech 'corridor' that runs, roughly, between Reading and Cambridge (Hall, 1987). This dynamic is reflected in increasingly complex commuter flows: the POLYNET project found evidence that the work-related travel was beginning to bypass central London entirely and display strong orbital components as well (Hall and Pain, 2006).

We face an enormous challenge in trying to understand and manage how the geography of places intersects with the geography of flows (Healey, 2005, p.151). As Graham (1997, p.118) noted, there is a "contradictory relationship between the city as a bounded piece of territory and telematics as real-time networks which enable users, by definition, to instantly transcend the limits of such bounded pieces of territory." Increasingly, we are seeing specialised, but complementary functions distributed across vast 'mega-city regions' that are under the control of no one set of plans or policies: the region as an economic entity does not map cleanly on to the region as an administrative unit (Dawkins, 2003, p.133). This challenge requires what government has often termed 'joined-up thinking' because there is no longer a coherent, integrated 'territory', but rather a fluid, flexible, and complex set of space/time relations (Healey, 2005, p.150).

1.4 *Overview of Dissertation*

One of the key shortcomings of the POLYNET study identified by Hall and Pain (2006) is the absence of reliable data on information flows. Thus this research began with a deceptively simple objective: to obtain data that would allow the mapping of informational flows across the Greater South East of England region, and I set out to obtain telecommunications data from a fixed or mobile network operator. Phone data has two critical advantages over most other types of relational data: extent and resolution. Unlike most infrastructure measures (*e.g.* traffic), it is possible to sample the entire phone network over an arbitrarily long period of time without incurring additional collection or survey costs. And unlike Internet Protocol (IP) traffic such as email or web requests, whose resolution is quite low and locational data quite misleading (Hall, 2007a, p.71; Dodge and Kitchin, 2001, p.3), it is possible to localise fixed and mobile callers with a reasonable level of precision.

A more subtle issue is the problem of causation: there are *no* data sets in existence that would enable a researcher to take a longitudinal view of how telecommunications usage has changed in the past twenty to thirty years—the volume of data to contend with is simply too massive—and so we are only able to demonstrate correlation. That said, we *can* revisit analyses of business location strategy that predate today's omnipresent ICT environment: by turning back to such early and important thinkers as Marshall (1890 [1948]), Weber (1909 [1969]), Haig (1926a,b), Christaller (1933 [1966]), and Lösch (1954 [1973]), we can establish a solid foundation upon which to build a theory of transport and telecommunications infrastructure and its complex relationship with industrial location.

Research Limitations

There are four important limitations to this research that are worth mentioning here: the first is that I will not be examining in any great depth the drivers of household locational decisions, even though these are obviously relevant to this work. For more information on this aspect of household preference, the reader can turn to the work of those, such as Florida (2002a,b) and Glaeser (2006), who have made cases for the relevance of the residential and recreational preferences of skilled employees (particularly in cultural industries) to urban and regional economic development. However, in this work I will largely treat the location of labour as a given, handling it as an input in much the same way that authors such as Weber (1909 [1969]) do.

The second limitation is that I am not considering the role of rent in any formal way: it will be assumed that central business district (CBD) properties are generally more expensive than equivalent suburban ones, and that some companies have a greater interest in, and ability to pay, city-centre rents. What interests me is *why* the willingness of firms to pay exorbitant central city rents varies so greatly at a time when so many suburban sites offer a cheaper base of operations. I will not be considering in any depth the mechanics of whether and how firms outbid one another for a given location.

I will also only be considering those transportation and communications networks that are relevant to the movement of people and information. So while our freedom to live either on top of one another in massive conurbations or in remote parts of the Highlands or western America *also* depends on a host of other networks—the most notable being sewerage and power—these will not be examined in any detail here. Again, their availability will be taken as precondition for office or household relocation. Readers wishing to know more about these other systems should read Graham and Marvin's *Splintering Urbanism* (2001).

Finally, I have deliberately excluded the 'New Economic Geography' (NEG) from consideration in this work. There are several reasons for this, the most basic of which is that NEG is principally focussed on equilibrium states and external shocks, to the exclusion of the ongoing internal adaptation that I, like Garretsen and Martin (2010, p.150), feel to be essential to regional development. A second reason is that the basic parameters, such as spillovers and transport costs, are usually assumed to be constant in an NEG model (2010, p.145), and this is something that I feel does not hold in reality. Ultimately, the basic NEG model (see summary in Garretsen and Martin, 2010, p.134) and its offspring simply are not that relevant here: there is no reason to pursue formal modelling when I am principally interested in how firms and entrepreneurs reach locational decisions rooted in an understanding and analysis of their own, unique mix of requirements.

Research Context

	Deconcentration School	Restructuring School
City and region conceptualised	Postindustrial city (Bell, 1973; Hall, 1997); E-topia: smart city (Mitchell, 2000); Aerotropolis (Kasarda, 2000a)	Post-fordist city (Occelli, 2000); Informational city (Castells, 1989); Global city (Sassen, 1991); Network city (Clark and Kuijpers-Linde, 1994)
Scale	Metropolitan and intrametropolitan	Metropolitan, regional, global
Urban/digital space	Geography of accessibility and opportunity (Janelle and Hodge, 2000); Hybrid space (combination of physical and virtual space); Internet-backbone space (Moss and Townsend, 2000)	Multimodal and digital connectivity (Hepworth and Ducatel, 1992); Space of flows versus space of places (Castells, 1996 [2000]); Synergistic relations between urban place and electronic spaces (Graham and Marvin, 1996)
Research traditions	Spatial interaction models (aggregate data, urban scale); Probability choice models (individual behavior)	Case studies; Comparative studies of cities using aggregate data
Planning challenges	Congested cities: fragmentation of activity in hybrid space and information technology synergies with automobile society result in travel demand that overwhelms transportation infrastructure	Interjurisdictional bidding wars for global capital. Congested cities: IT synergies with automobile society and just-in-time production result in travel demand that overwhelms transportation infrastructure. Dominance of space of flows over space of places
Information-age landscapes	Sprawling polycentric: (1) High in mobility, low in accessibility, spatially mismatched; (2) connected/disconnected from Internet backbone (network of a few metropolitan cities)	(1) Polycentric and intensely extra-networked by land, air, water, and digital means to global and regional urban systems; (2) deeply digitally and multimodally intra-networked, albeit all the more socioeconomically segregated, physically overextended, and stuck in traffic

Table 1.1: Deconcentration and Restructuring Schools (after Audirac, 2002, p.214)

Audirac (2002, p.212) suggests that there are two basic theoretical approaches to the contemporary shifts in patterns of economic activity: deconcentration and restructuring. Both schools of thought recognise the importance of technological change to urban form, but they differ in what they believe the impact of ICT to be (2002, p.213). The deconcentration approach is particularly common in neoclassical economics and generally expects ICT to "[dissolve] the importance of distance and permitting footloose economic activities to relocate to lower-cost exurban, rural, and offshore areas" (2002, p.215). In contrast, the restructuring school argues that the need to control and coordinate increasingly complex spatial configurations is actually increasing the need for managerial functions to cluster at strategic sites (2002, p.215; see also Sassen, 2002). The principal differences between the two approaches are summarised in Table 1.1.

A related methodological division exists within the outputs of the 'global urban networks' research community that is studying the relationships between 'world cities' (cf. Taylor and Walker, 2001; Taylor, 2005; Derudder et al., 2003). One set of approaches has tended to focus on corporate structures, while the other has relied on the analysis of infrastructure to establish which cities sit at the heart of globalisation processes (Taylor et al., 2002, p.93; Derudder, 2008, p.561). In the first case, most measures of connectivity are, at best, guess-timates: network metrics are generated by calculating the *potential* interaction between cities based on the number of employees in each office and whether such information was available on the firm's web site (Taylor et al., 2001; Derudder et al., 2003; Taylor, 2005). In the second case, the architecture of the network may not adequately represent the phenomena being studied: for example, although many flights pass through London, emphasising its centrality, many passengers are actually passing through on their way to another destination entirely (Derudder, 2008, p.564).

Theoretically and empirically, my own work sits somewhere between these two schools, though this is hardly surprising since there is a great deal of overlap between them. My argument is that these processes are all inter-related: that dispersion is highly selective and predicated on telecommunications access, and that concentration in global hubs is equally selective and largely rooted in what *cannot* be communicated via ICT. These stresses affect all firms, but to different degrees, and in understanding the interplay of travel and communication needs we can flesh out the locational strategies of firms across a range of industries. This argument is much in keeping with Graham's point that the financial services "…do not simply decentralise to the periphery of cities or further afield, to rely purely on electronic interaction; rather, such processes seem to fashion complex new intra-urban geographies of service location" (2002, p.77).

Empirically, the data upon which this work is based address some of the critical issues identified by Derudder (2008) and Taylor et al. (2002) with respect to current research efforts. So although the data from the British and American operators reported in this thesis are necessarily 'state-istics' (Taylor et al., 2002, p.96) by virtue of being supplied by telecoms operators rooted in nation-states, it also supplies us with the vital *trans*-national perspective of real inter- and intra-urban links. Furthermore, not only are we able to measure the actual level of interaction, but we can do so without regard to the risk that a route becomes 'unnaturally' important through the simple expedient of its being the only one between two sets of points (Smith and Timberlake, 2002).

Infrastructure and Regions

Chapter 2 is rooted on the idea that we cannot understand the impact of telecommunications on locational decisions without first contextualising it amongst the variety of transport infrastructures—road, rail, sea, and air—already in place. Parsing out of the effects of the land-line or mobile phone in today's environment would be impossible, but by turning to the work of Christaller (1933 [1966]) and Lösch (1954 [1973]), we can work with a simpler set of networks and use these authors' approaches as a foundation for an analysis of these infrastructural relationships. However, running these theories forward into the present highlights the lack of a coherent theoretical approach to the tradeoffs between travel and communications in a digital era, and so bridging this basic divide will be one of the key tasks of this second chapter.

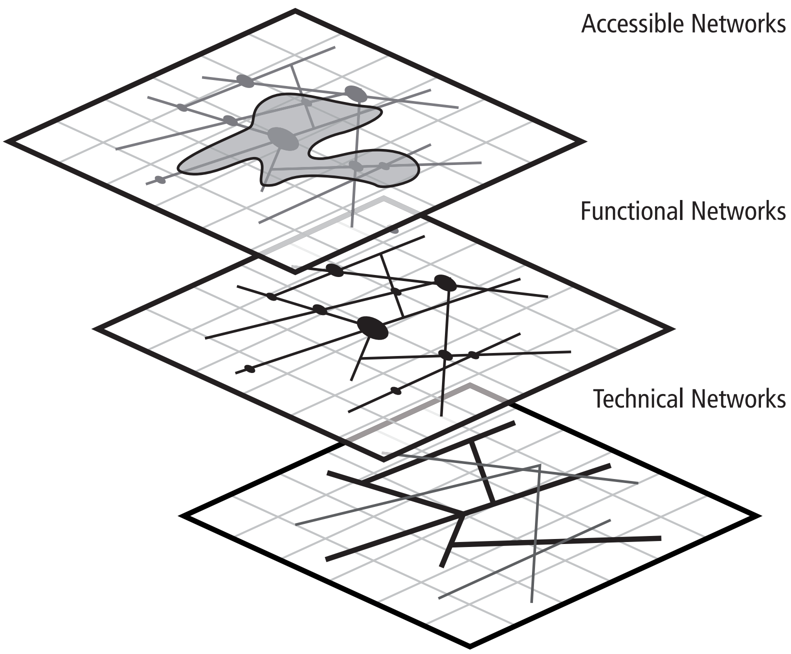


Figure 1.3: Layers of Network Analysis

Drawing on a three-tiered approach to infrastructure advanced by Drewe (2005, pp.111–112), in Figure 1.3 I will take as a starting point the technical networks that underpin the movement of material, people, and data across local, national, and global scales. However, while the operators of these networks may see themselves as operating in competition with one another, from the standpoint of *functionality* they form an integrated network of nodes and links of varying sizes, scopes, and capacities. Approaching infrastructure through the lens of economic costs enables use to build a broader model in which it is the *accessibility* and *bandwidth* of different networks that constrains firms' locational decisions. However, we will also need to bear in mind that any viable "theorisation of networks needs to consider the actors and infrastructure that constitute the links in the network, rather than simply assuming that the nodes are the only places of significance" (Fowler, 2006, 1437).

Firms, Markets and Risk

Accordingly, in Chapter 3 we will consider how firms configure themselves in space so as to manage the flow of goods and information. We will return to the foundations of firm location theory, and use the findings from Chapter 2 to reframe it in terms of multi-modal accessibility instead of purely geographical or geometrical characteristics (Knoben and Oerlemans, 2008, p.386). However, as we move through Chapter 3, we will be keeping an eye out for the impact of information on locational decisions since this dimension is largely missing from the cornerstone text by Weber (1909 [1969]) and from subsequent work on the role of risk in firm organisation by, for instance, Coase (1937).

By drawing on Clark and O'Connor (1997), I will show that Coase's underlying insight into the role of risk in the structure of the firm is played out in space as well. Simply put, products, firms, and markets have spatially-determined risk profiles to which firms can respond in a variety of ways: the most important of these is reconfiguration, but the flexibility of the firm to adjust its internal structure is also affected by the nature of the transactions in which it takes part. We will treat inter-firm and intra-firm interactions as transactions with two stages: search and execution, and see that, depending on the distribution of the costs between these two phases and on the frequency with which these costs are encountered, the firm will pursue very different strategies.

Agglomerations and Clusters

From time to time, the concentration of firms in a particular area grows to the point that it somehow becomes more than the sum of its individual parts: the unprecedented growth of Silicon Valley, and the resurgence of the cultural markets in cities like New York and London, point to the dynamic impact of clustering on economic development. Taylor has suggested that we can 'crudely' think of spatial organisation and the structure of cities area "as the result of a combination of two sets of materialist mechanisms: agglomeration processes creating economic clusters within cities, and connectivity processes creating economic networks between cities" (Taylor, 2009, p.2550). Since we have already considered the latter case in Chapters 2 and 3, Chapter 4 is primarily concerned with the former case and seeks to explain why we cannot treat the firm in isolation, but must factor in its relationships with the competing and collaborating firms around it.

The Knowledge Economy

In Chapter 5, we turn to the growth of the knowledge economy, and seek to connect it back to our observations about networks, firms, and clusters. Brinkley et al. (2009, p.9) connect the rise of knowledge work to three feedback mechanisms: first, the increase in power and decline in price of 'general purpose ICT'; second, improvements in logistics and travel; and third, better living standards 'creating well-educated and demanding consumers with voracious appetite for high value added services'. And we will also see how the characteristics of knowledge work are altering the market for both skilled, creative people and their principal output: new ideas.

Methodology & Analysis

The approach of this work rests in part on what Lazer et al. (2009) term 'computational social science', which seeks to build models of large social systems "using their reflections in massive data sets" (Kleinberg, 2008). Using unprecedented data sets supplied by major British and American networks, I will be tracing the ways in which telecommunications serves as a marker of place and of activity, enabling us to analyse city-regional systems on a much larger scale and with much higher resolution than previously possible using, for instance, commuting or employment data. I will also be using an 'eigenplace analysis', introduced in Reades et al. (2009) and Calabrese et al. (2010), to explore how these systems can be analysed according to varying similarity measures.

The novelty of the data sets, together with the challenges associated with exploring such massive amounts of data, mean that substantially more in the way of illustrative figures and tables than could feasibly fit into a single chapter was produced. To preserve the readability of the analysis, supporting material that was not integral to the analysis itself, but which nonetheless provided important supplementary context for the findings, was placed in three appendices. The first, Appendix A: Aggregate Spatial & Temporal Calling Data, presents aggregate call data on domestic and international calling. The second, Appendix B: Location & Telecommunications Quotients, reports additional findings from the Telecommunications Quotient (TQ) analysis, together with figures showing the distribution of industrial activity in New York City, London, and the Greater South East of England (GSE). The third appendix, Appendix C: Eigenplace Analysis, supplies additional eigenplace analyses along with supporting material on the clustering results. Finally, Appendix D: Data Management & Processing provides a general overview of the storage, processing, and analysis of the data.

1.5 Summary

The ability to communicate at any time, and in almost any place, cannot help but change the way that individuals and firms interact with one another. Today, we work from home and catch up on social obligations at the office. We 'network' both face-to-face and via a panoply of digitally-delivered services such as LinkedIn, Facebook, and MySpace. We can already videoconference and share travel photos online with relative ease, but more radical change is on the way: some smartphones—employing the combination of GPS, a digital compass, and an accelerometer—now enable a user to point his or her phone at a landmark and have the phone retrieve information about the referenced object using its calculated location in space (Jonietz, 2007). Within twenty years such an interface will seem quaintly limited.

Anticipating these changes, Graham and Marvin (2000) noted that it was no longer helpful to think of telecoms networks as being distinct from the built environment since the two are increasingly inseparable, the one influencing the growth and adaptation of the other. Or as Mitchell[5] put it:

> [constructed] spaces will increasingly be seen as electronically-serviced sites where bits meet the body—where digital information is translated into visual, auditory, tactile or otherwise sensorily perceptible form and vice versa. Displays and sensors for presenting and capturing information will become as integral to rooms as old-fashioned windows; network connections…will be as essential as doors
>
> *Mitchell, 1994, p.63*

[5] This article also contains a retrospectively fascinating exercise in 'futurology': "…imagine the moment when all your personal electronic devices are seamlessly linked in a wireless bodynet that functions as an integrated system and connects to the worldwide digital network. Your Personal Digital Assistant will allow you to program your VCR, listen to pager messages through your Walkman, display location coordinates from the Loran positioning system on your smart spectacles…" (Mitchell, 1994, p.64).

In a very real way, these communications networks are already so pervasive, and so seamlessly embedded in the fabric of everyday life that we only become aware of their (non-)existence when they fail—as they still do under the heavy load of an event or an emergency—or when we are in one of a vanishingly small number of remote physical locations where access is still impossible (cf. Burkeman, 2007).

Navigation of this blurring interface between virtual and physical cities implies significant change in how we use space and time to pursue our personal, social, and professional interests. Until recently this interface was largely hidden from researchers, but the need to explore informational flows across cities and nations is becoming increasingly apparent; to put this in planning terms: "ways of seeing and understanding the city inevitably inform ways of acting on the space of the city, with consequences that, in turn, produce a modified city that is again seen, understood, and acted on" (Sandercock, 2005, p.161). How we deal with the consequences of our newfound ability to see, understand, and act will have an enormous impact on the shape of the 'cities of tomorrow'.

2
Infrastructure and Regions

2.1 Introduction

This work begins with a fairly detailed review of two of the founding texts in spatial economics—and although the works of Christaller (1933 [1966]) and Lösch (1954 [1973]) are principally concerned with the physical movement of goods and, to a lesser extent, services, they provide us with the basic framework for understanding the economic costs of transport and travel in an era when telecommunications had only begun to reshape regional, national, and inter-national systems. Beginning with these theorists helps to make two things clear: first, that the assumption of a 'flat plain'[1] is profoundly misleading; and second, that a common terminology by which to understand and compare very different types of infrastructure—both digital and physical—has been largely lacking. And although it is beyond the scope of this thesis to put forward a fully worked-out resolution to these two problems, I intend to outline some useful ways of approaching these challenges and moving our thinking forward in these areas.

However, that is to look ahead to the conclusions of this chapter, so let us return to the basic question: how do telecommunications networks support or supplant the usage of other infrastructure networks, and what does this imply for the evolving distribution of economic and social activity across space? To address this issue we need to be able to compare wildly divergent types of infrastructure simultaneously, an important failing of many extant analyses is to treat each one in isolation (Feitelson and Salomon, 2000, p.48). So the core aim of this chapter is to develop a generic framework for the analysis of infrastructure networks that draws on nearly one hundred years of thinking on the relationship between markets, networks, and space.

Christaller began by asking why some towns grow into cities while others remain small, and whether there is an order to this pattern of growth (1933 [1966], p.2)? The essence of his theory is that some towns become 'central places' for the exchange of goods and services by virtue of economies in transport or production. The central place co-exists symbiotically with a hinterland: less complex goods such as food are imported to the centre, and more sophisticated goods make their way outwards to rural and suburban consumers. In an ideal environment, which is to say one with no natural boundaries or strong historical

[1] In the technical jargon of economics and planning this is often referred to as an 'isotropic surface'.

influences, this process would be expressed as an interlocking hierarchy of markets in which every good is available from somewhere at a price determined largely by the economic cost of transporting goods to the consumer from a central place.

Central Places: The Christallerian view of hierarchical relationships between towns and cities is a compelling one because it is simple to grasp and implies a rational order to regional economies. Graham and Marvin (1996, p.62) report that planners in County Durham once suggested "the destruction of villages and towns so that [the] settlement system accorded better with the theoretical perfection of central place theory." Thankfully, the era in which planners consider demolishing towns that 'did not fit the theory' is now long-passed, and a recent review of regional development literature identified two interlinked trends that challenge the existence of formal hierarchy: first, the internal coherence of regions has weakened thanks to improvements in communications and transport; and second, these same improvements are leading to increasingly complex patterns of movement which negate the traditional regional boundary and enable employees to work from areas 'offering service or quality-of-life benefits' (Dawkins, 2003, p.133).

Spatial Competition: Working from a model of inter-firm competition in space, Lösch (1954 [1973], p.122) derived a pattern of market areas that was remarkably similar to the top-down model advanced by Christaller even though many of the premises were fundamentally different. Generally speaking, the extent of any one firm's market is determined by 'the combined influence of scale economies and transportation costs' (Dawkins, 2003, p.137). So if scale economies dominate transportation costs then production will tend to occur at a single point, while if transport costs are high relative to economies of scale then firms will operate from anywhere there is a lack of competition (*ibid.*).

However, the addition of demand substitution, in which consumers replace a high-priced good with a lower-priced one that satisfies the same need, as well as the detaching of production from central places, complicates the resulting structure. In effect, because the markets are attached to firms and not to settlements, there are many overlapping market areas and not just one hierarchy. Nonetheless, in Lösch's model, regions may still have a central metropolis and neighbouring areas of more- and less-intensively used land; and as with Christaller, the increasing economic costs of delivering goods and services over a distance determine the boundaries of markets.

Network Flexibility: Although both Christaller and Lösch were profoundly interested in transport infrastructure as the 'glue' that holds together a regional market, there is comparatively little explicit consideration of the impact of complementarity or substitutability between competing infrastructures. The backgrounding of transport infrastructure in regional studies becomes an important issue with the emergence of what Feitelson and Salomon (2000) term 'upper-tier' infrastructures such as High-Speed Rail (HSR) and electronic toll-highways, but it reaches a critical point with the addition of telecommunications.

Simply put, Feitelson and Salomon (2000, p.459) note that substantial evidence exists that transport infrastructure is not simply a reflection of regional economic development, but plays an active role in shaping the location of commercial centres and the level of economic integration between regions. However, this is not a straightforward technologically determinist argument: the authors argue that transport must be seen as a necessary, but not sufficient, condition for economic growth (Feitelson and Salomon, 2000, p.460).

Feitelson and Salomon's model enables us to consider the tradeoffs between different transport and communication networks, and to offer up a more generalised model of infrastructure flexibility as it affects accessibility. In sum, it is by examining distance *within* networks—not across some abstract plain—and comparing the strengths and limitations of each that we are able to get to grips with the underlying parameters of spatial strategy. And it this adaptive approach to spatial analysis will set up a more detailed exploration of firm behaviour in Chapter 3.

2.2 Theory of Central Places

The core concept of Christaller's work is the central place, and its economic relationship both to its hinterland (also termed its complementary region) and to the larger network of other central places beyond. Or as Christaller (1933 [1966], p.16) puts it: "the chief profession—or characteristic—of a town is to be the center of a region." This relationship is illustrated in Figure 2.1, but the key point to keep in mind is that the central place is not a singular site of a specific size, but rather a 'developmental level' within a functional hierarchy used for regional analysis. For instance, we can envision a market town being *simultaneously* the central place for a rural hinterland of farms and villages, *and* part of the hinterland of a much larger conurbation such as a city.

This hierarchy means that in central place theory the highly-connected central place binds together the nodes 'below' it into a coherent system, and that the centre-periphery pattern repeats at multiple scales. With each step up the hierarchy, the centre grows increasingly sophisticated in terms of the goods and services that it supplies to its complementary region, and its market area grows in overall extent. To put this in network terms, the central place acts as the interface between a local trading network of which it is the primary node, and a regional or national flow of goods and services within which it is just one node amongst many at the same level of functional specialisation.

Simplifying Assumptions

HOMOGENEITY: Like most economists, Christaller presumes a homogenous plain on which to test out his theory of central places. Taking this approach enables Christaller (1933 [1966], p.27) to focus on the spatial

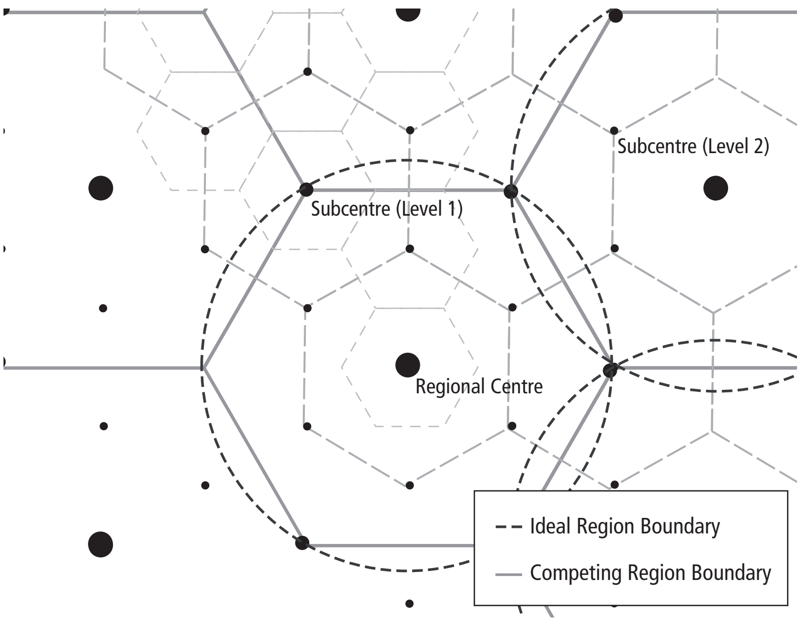


Figure 2.1: The Hierarchy of Central Places

characteristics of consumption and so does not preclude variation in the distribution of population, demand, and supply. This assumption frees Christaller to focus on the characteristics of central places, and how their 'completeness' distinguishes them from specialised places such as farms or mining and company towns (1933 [1966], p.23).

Central places are concentrations of differentiated and specialist demand, and so their centrality is not purely a function of population (1933 [1966], p.70), and this 'localisation of functions' decouples centrality from simple measures of city size (1933 [1966], p.71). Implicitly, however, Christaller (1933 [1966], pp.68) expects a geometric distribution of central places that would accord with similar observations about city size made by Zipf (1946) so it is difficult to see how the two could not be related.

Economic Costs of Transportation: What knits the hierarchy of places together is transportation, which is essential to the division of labour since "with limited traffic possibilities (Verkehrmöglichkeiten), the division of labor is possible only to a limited degree" (Christaller, 1933 [1966], p.48). There is, for instance, comparatively little use for a patent lawyer confined to a small town by poor transport links; it is absolutely vital that the specialist be able to reach a central place of sufficient size to have clients with this sophisticated need, and that they also be able to do so at a sufficiently low economic cost. So, without cheap transport the specialisation associated with higher-order centres simply does not occur, and economic development is retarded in significant ways.

The crucial assumption in Christaller's work is that the economic costs of transportation increase linearly with distance (1933 [1966], p.22). Cost needs to be understood here in an economic sense, which means not just a monetary amount, but a full costing that incorporates factors such as travel time, speed, frequency, comfort and risk (1933 [1966], p.52). By way of example, an expensive, but fast and frequent service between two places is not necessarily more costly from an economic standpoint than a cheap, but slow and delay-prone one.

The Centrality of Goods

The centrality of places is reflected in the centrality of the goods that they carry: central goods stand in contradistinction to both dispersed and indifferent goods which, as their names suggest, are either produced outside the central place, or (potentially) in both the central place and in the hinterland simultaneously. As Christaller (1933 [1966], p.19) puts it: "The goods being produced at the central place, just because it is central, and the services offered at the central place, will be called central goods and central services."

In general, central goods seem to be synonymous with 'higher order' goods: these may be social or cultural in nature, such as theatres or restaurants (1933 [1966], p.34), but they would also include the output of any tradespeople unable to ply their trade in the hinterland because of an insufficient concentration of local demand or ability to pay. Consequently, the variety of goods on offer in a given central place reflects its position in the overall network: "[places] of lower centrality thus supply only the lower-order functions, whereas places of higher centrality fulfil these lower-order functions plus at least one service function of a higher order" (Klemmer, 1978, pp.55–56).

There is a kind of recursive reasoning here: what defines the central place is that it produces central goods, and central goods are the ones that can only be produced at a central place. As a result, Christaller's claim that central goods are "produced and offered at a few necessarily central points in order to be consumed at many scattered points…" (1933 [1966], p.19), while dispersed goods are produced in many places still does not adequately define centrality in any measurable way.

The Range of a Good

However, combining the distribution of demand with the economic cost of travel yields the idea that goods and services have a range over which they can be profitably sold (1933 [1966], p.54). The minimum range of a good is determined by the smallest area containing enough customers to make a profit. The maximum range is the distance at which transport costs have mounted to a level where no one is interested in purchasing it. The furthest distance from the central place at which a good is purchased constitutes its market boundary (1933 [1966], p.58). Inverting the relationship between place and consumer, we could also say that the maximum range of a good is the furthest that a customer—or their 'travel proxy' such as a travelling salesman or postman—would be willing to travel in order to procure it (1933 [1966], p.21).

Remember, however, that the range of a good is ultimately determined by economic costs, and so range may also vary with social norms such as lifestyle or economic factors such as income. In other words, range has a "thoroughly subjective element" (1933 [1966], p.51) and may be affected by the distribution of demand, income and, crucially, infrastructure. For instance, a concentration of wealthy consumers will tend to reduce the minimum range of a costly good (1933 [1966], p.68), but high-value goods will also tend to have greater maximum ranges because transport costs are a smaller component of the final price. Table 2.1 summarises the ways that different combinations of ranges can affect overall regional development.

Minimum Range	Maximum Range	Effect
Small	Small	Small places develop well; Large ones develop poorly
Small	Large	All develop
Large	Small	All develop poorly†
Large	Large	Small places develop poorly; Large ones develop well

† Meaning that the minimum range is relatively large within a framework where the maximum range is quite modest, not that the minimum range is somehow greater than the maximum.

Table 2.1: Interactions between product range and central place development (Christaller, 1933 [1966], p.121)

Because transport acts as a mediator of trade between places, changes in the usage or distribution of routes affects overall regional structure (1933 [1966], p.47). This gives rise to the 'traffic principle' of development, in which the existing hierarchy may realign itself around new infrastructure, potentially producing significant deviations from the ideal 'market principle' derived from consumption alone (1933 [1966], p.73). Thus the *same* good—offered at comparable central places with different qualities of infrastructure—may have different ranges (1933 [1966], p.50), and places able to produce or ship goods at a lower cost can increase their market area at the expense of their neighbours.

In other words, cheaper, faster, and more comfortable modes contribute to the centralisation of consumption by reducing the perceived cost of travel; this change arises because the point at which it becomes a matter of indifference to the consumer from which place they purchase the good shifts outwards from the more efficient place (1933 [1966], p.40). At the limit, transport network improvements may mean that a poorly-provisioned central place ceases to be able to sell its goods profitably anywhere because of competition from better-connected neighbours, and the central place itself (or at least the higher-order goods and services that it previously supplied) ceases to be viable (Beckmann, 1978, p.17).

Agglomeration & Technology

Agglomeration: In Christaller's model, agglomeration—the physical clustering of firms in space—may arise from the organisational requirements of coordination and capital (1933 [1966], p.21). However, supply-side agglomeration (the benefits accruing to firms, not consumers) remains weakly-developed, and the central place is principally a 'stimulus for consumption' (1933 [1966], p.42) since the grouping together of a wide variety of goods and services in a single place enables consumers to reduce the total economic cost of their shopping trips. Today we might call this 'trip chaining', but it remains a fact that higher-order centres enable consumers to address multiple needs with a single journey (1933 [1966], p.43), and so higher order centres will tend to draw customers away from lower order ones with a more limited selection of goods (1933 [1966], p.50).

However, radical changes in infrastructure create the opportunity for a significant reordering of the existing hierarchy: a rail station on the outskirts of town may undermine a once-vibrant town centre "through the development of an auxiliary central place at the station and through the emigration of consumption of central goods to a nearby central place of a higher order" (Christaller, 1933 [1966], p.105). Contemporary evidence of this process can be seen in the success of out-of-town 'big box' retailers in the U.K. such as Tesco or B&Q, and of full-service 'malls' like those at Bluewater or White City at the expense of traditional high-street shops (Conisbee et al., 2004). These retailers offer ample evidence of the 'traffic principle' at work: the scale of parking provision at these centres makes it clear that this is a form of transit-oriented, accessible development, even if we associate it with a host of negative externalities.

The accessibility effect can be seen around air and High-Speed Rail (HSR) infrastructure: Bertolini and Dijst (2003) coined the term 'mobility environment' to describe the way that these locations' multi-modal accessibility fosters their emergence as 'multi-functional concentrations'. Airport areas in particular are increasingly used by non-travellers for recreational purposes, and by businesspeople as a substitute for travel downtown to a meeting (*ibid.*). Bertolini and Dijst (2003, p.33) note that BAA (now part of Ferrovial) earns more from the management of commercial activity at Heathrow, Gatwick, and Luton than it does from airport taxes, while Schiphol earns more from real estate and concessions than from all aviation-related activity. For airports in general, retail can account for as much as one third of an airport's profit (BBC Four, 2009a).

TECHNOLOGY: Technology change—and Christaller (1933 [1966], p.101) specifically included the automobile, telephone, and radio amongst these—not only impacts the spatial logic of production and purchase for goods through its effects on transport infrastructure, it can also have effects on the good itself through an increasing division and specialisation of labour (1933 [1966], p.100). On the one hand, technologies that lower transport costs cause production costs to become a larger component of the final price, and so finding the places of cheapest production—in Christaller's model this is usually a large central place—becomes more important to firms. But on the other hand, technology can also bring into play new techniques of production, scheduling, and delivery, such that "certain types of goods which were previously offered centrally are offered dispersedly…" (1933 [1966], p.106). Eventually, products that could at one time only be procured at a central location become omnipresent, and their source becomes a matter of 'indifference' to the consumer.

This is why Christaller argues that all examinations of regional structure need to incorporate technical progress as a factor (1933 [1966], p.99). However, the overall pace of infrastructure change, by which we should also understand technological improvements to the existing infrastructure, also plays a role in the development of regions:

> We may hence conclude that if the train service develops slowly, and if long-distance lines are preferred, then the system of central places may be able to reform itself according to the propositions of the traffic principle. If the development is swift, however, or if local lines are preferred, then the scheme of markets will remain intact.
>
> *Christaller, 1933 [1966], p.114*

So during times of change, those central places that are located least favourably relative to the 'dominant' developmental trend will suffer most from a shift of consumer demand to alternative sources (1933 [1966], p.114). But rapid changes may actually reinforce (or least not significantly undermine) the existing hierarchy *even if* the change itself might appear to favour dispersion or decentralisation.

How might the rollout of wired and wireless telecommunications services fit into this model? The example of call centres, which sever the link between places of production and consumption entirely, is one for which Christaller's theory has no real place[2]. Apart from being able to state that these 'customer service factories' tend to make use of an accessible out-of-town location (Breheny, 1999, p.20), there is no obvious way to link such centres to a spatial hierarchy. Contrasting the physical mobilities of the 'pre-digital' era with the virtual ones available today, Audirac (2002, p.217) notes that "…accessibility in urban space combines with virtual accessibility, in what is now being called 'hybrid' space." This hybrid space seems to create an entirely new kind of 'placelessness' in which distance can, in principle, be sublimated.

[2] We will consider online shopping, another form of distributed consumption, later in this work.

Spatial Implications

So, changes to transport and technology should extend the market boundary of any given centre; and in a dynamic environment, population growth in a central place should stimulate local demand and, with it, the specialisation that triggers further development. For instance, a factory worker buys food from a specialist (*i. e.* a grocer), whereas the farmer grew his own (Christaller, 1933 [1966], p.34). Conversely, population growth in the hinterland may stimulate the growth of new central places or, alternatively, generate growth amongst pre-existing lower-order places that were once too small to support higher-order goods but now form a central place for a newly suburbanised population.

Similarly, income growth should stimulate the production of higher-order goods since more income remains for consumption after subsistence goods such as food and accommodation have been purchased

(Christaller, 1933 [1966], p.34). But as with population growth, the distribution of income growth matters: if it occurs in the existing central place then it will stimulate the further development of higher-order goods there, but if it happens in the hinterland then it may stimulate the development of a new centre that competes with the existing one. Moreover, the social distribution of income growth plays a role since a small number of very high incomes does not stimulate central markets to the same degree that a large number of slightly lower incomes might (1933 [1966], p.34).

In economic analyses, rising incomes also affect the cost of travel because the traveller's time is relatively more valuable to him or her. So when Lange (1978) adds the notion of 'search costs' to Christaller's model, he argues that this will favour the largest central places because "the greater the need for information prior to the purchase of a certain good, the more shops the consumer must visit, and the more time he needs [to do this]…" (1978, p.65). Note, however, that Lange seems to assume that search costs accrue linearly because the consumer must visit each shop in turn in order to determine if the product is in stock and suitable for purchase. Telecommunications, and in particular the Internet, largely obliterate this approach except where products are not searchable in this way. Consequently, the extent to which telecoms may undermine or reinforce the existing central place hierarchy is difficult to determine and they seem to exist largely outside of any meaningful hierarchical principle.

Summary

Christaller's model of regional development, rooted in the growth of central places connected by short- and long-range transportation infrastructure, provides us with an important starting point for our analysis, but several important gaps in this model call into question any broader application. First, nearly all of the factors affecting firms and households are exogenous making it difficult it to understand how changes occur within the urban system (Vance, 1970, p.151). And recent research indicates that the stability of city size distributions masks substantial change at the level of individual cities, which may move up or down the size ranking rather quickly (Batty, 2006, pp.592–596).

Moreover, a good case can be made that Christaller's approach simply takes the *extant* situation in Germany and retroactively generates from it a theory, while largely failing to explain the situation in countries without a history of feudalism (Vance, 1970, p.103). Vance went on argue that other regions would develop along very different lines and that 'at the beginning trade is predicated on external conditions and lines of flow to other markets' (*ibid.*). He claimed that the development of the port cities along the southern edge of England and of the City of London could be connected to the emergence of an 'intelligence complex' that allowed these areas to exploit information about remote markets (1970, p.149) and had little to do with 'centrality' as Christaller defined it.

A second issue is that there is no scope for demand substitution, yet the idea that if a product is too expensive then you either buy it from somewhere cheaper or you do not buy it all (1933 [1966], p.22) does not reflect the reality that there is usually an array of alternatives for many goods and services. This is also, it should be noted, 'inimical to entrepreneurship' (Vance, 1970, p.140), and is in many ways a "geography of imposed order" (1970, p.166). So although Table 2.1 actually makes it possible for multiple *systems* of central places to coexist at various scales, Christaller nonetheless appears to imply a degree of hierarchical consistency in the structure of places and markets that negates transformative change.

An earlier review of Christaller's theory drew contradictory conclusions on the degree to which this matters: Klemmer concludes that Christaller's model "requires the existence of an internally consistent hierarchical system…" (1978, p.57), but Beckmann suggests that having a hierarchy of goods "is not the same as saying that a strict hierarchy of central places results" (1978, p.14). To my mind there does not appear to be any basic prohibition—other than Christaller's own—in the definition of central goods that bars a lower-order town from specialising in the production of a higher-order good to be offered for sale through a 'senior' central place; however, the basic problem here is that as soon as we allow this to happen, or permit factors such as demand to vary across space (or time) then it becomes impossible to definitively connect centrality of goods, or scale of markets, to centrality of places.

An additional issue with Christaller's approach is that the relationship between economic cost and physical distance, which would have been very nearly linear in his day, has largely broken down. For instance, the hub and spoke air travel network reinforces the dynamic by which well-connected cities are actually closer to one another in an economic sense than they are to their complementary regions. Hall (2005) contrasts travel times between London and Manchester and London and Oldham or Rochdale as an example of the way that peripheral nodes in British regions have been excluded from the core high-speed network even when they are quite physically close to major hubs.

In spite of these important *lacunae*, in some ways Christaller's interest in the tertiary (*i.e.* services) market puts him ahead of his time. Rising incomes for many mean that we are increasingly preoccupied with the cost of consumption, and for residents and visitors alike "cities offer 'agglomerations of consumption'—that is, easy access to lots of different goods and services within a fairly small area. Many cities are sites of the growing 'play economy'—retail, tourism and leisure" (Athey et al., 2007, p.17). There is also the intriguing implication in Christaller's 'traffic principle' that the sheer pace of telecommunications infrastructure change may mean that it has correspondingly less impact on our towns and cities: we are still very much stuck with our 1960s and 70s rail and air infrastructure even as our telecommunications networks have undergone multiple major upgrades.

In fact, a fleeting reference to 'polycentral' development even seems to place Christaller (1933 [1966], p.23) squarely within the much more recent debate on polycentric development (cf. Champion, 2001; Copus, 2001; Davoudi, 2003; Hall and Pain, 2006; Kloosterman and Musterd, 2001); however, his model does not cope particularly well with true functional polycentricity. This issue arises because there is no way to measure or determine centrality when the products and services on offer in central places *complement* one another instead of competing with each other. For instance, the Western Crescent's dominant role in Information and Communications Technology (ICT) in the South East of England (Hall, 1987), and the concomitant *lack* of ICT employment in London—manifestly a higher-order place—shows that we seem to ending up with highly specialised places instead of hierarchically structured ones.

A rather remarkable commentary by Taylor (2009) in *Environment & Planning A* constitutes a kind of back-handed tribute to the continuing power of Christaller's analysis[3]. Taylor is responding to a peer reviewer who indicated that "the authors appear to be saying that inter-city relations are essentially non-hierarchical which I find a little strange" (2009, p.2550). Taylor is astonished to find that the "legacy of central place theory with its neat hierarchical placing of cities appears to continue to be influential outside its original discipline" (2009, p.2550). While I would concur—for reasons that will become clear over the course of this chapter—on the limitations of hierarchical analyses, we have nonetheless explored several aspects of Christaller's thinking that may still be considered relevant to specific aspects of contemporary regional analysis.

[3] And see also Nicolas (2009) for another recent critique of the persistence of hierarchical central place thinking in theory and practice.

2.3 *Theory of Spatial Competition*

Where Christaller adopted a 'top-down' analytical approach, in Lösch's (1954 [1973]) 'bottom-up' model the effects of space are not expressed solely through rising transport costs, but also through inter-firm competition and demand. The focus on the firm, together with the addition of product substitution and a movement away from the notion that all transactions occur at a point (Lösch, 1954 [1973], p.139), means that markets cease to have the clear, hierarchical structure that they did for Christaller and also puts Lösch's approach more in line with contemporary micro-economics.

However, a critical difference between Lösch's model and those of the more traditional branches neo-classical economics is that because of spatial discontinuities (*i. e.* varying levels of accessibility) demand for a particular good within a given firm's market area may actually exceed supply, creating surplus profits indefinitely (1954 [1973], p.120). In other words, areas may exist where demand exceeds supply but where this surplus is insufficiently great to permit new firms to enter the market, and that as a result 'excess' or 'leftover' profits may endure (1954 [1973], p.6).

Simplifying Assumptions

Homogeneity & Utility: Like most economists, Lösch presumes that inter-firm competition takes place on a flat plain across which transport costs accrue in a linear fashion. However, unlike Christaller, Lösch is careful to include the idea that there is variation in the distribution of consumers, their preferences, and their willingness to pay. Here, their willingness is a function of *both* economic cost—comfort, speed, and so forth—*and* utility. This means that consumers also consider such diverse factors as their social networks, the climate, and their enjoyment of a line of work (1954 [1973], p.236). In Lösch's view, the inability of economics to accurately define 'utility' for any one person or organisation (1954 [1973], pp.224–225) implies that an empirical solution to the question of individual and firm location will necessarily depart substantially from his avowedly ideal theory.

Consumption & Substitution: Significantly, we also find that both production and consumption can depend on distance (1954 [1973], pp.6–7). For instance, within some specified distance of a retail location, shoppers at, say, Ikea have a choice about the 'form of consumption' for their furniture: it may be assembled on-site by specialists or collected in-person, but beyond that limit the furniture is only available as 'flat-pack'. A more subtle example comes from the steel industry: it is costly to transport poor-quality ore over long distances and the returns are modest, so the ore is likely to be processed locally for use in cheaper products. In contrast, a high-grade ore, even if it is more costly to extract, retains sufficient value that it is worth shipping to high-tech mills capable of making more advanced products. Japan's steel mills, for instance, are entirely dependent on ore shipped in from abroad, often as far away as Brazil (Engardio, 2009).

The picture becomes more complicated still with the addition of substitutability, such as that which arises from the distinction between finished and unfinished goods. Unfinished goods such as timber are frequently passed through intermediaries and sold on to a wide range of firms operating in very different markets. Consequently there is a strong incentive to standardise unfinished goods since it creates the potential for economies of scale for both for suppliers and intermediaries. However, this process also makes unfinished goods more readily comparable and, consequently, substitutable for buyers.

Spatially, substitutability is expressed as a 'harder' market boundary because shipping costs are the only distinguishing feature and one might as well buy from the closest supplier (Lösch, 1954 [1973], p.169)[4]. In contrast, the lack of substitutability for finished goods—whose demand may be affected by sociocultural factors—means that their markets will have 'softer' edges, and may even overlap substantially. So while timber may be sourced from the cheapest supplier, we would expect that finished furniture would not: even though they may serve the same ultimate function, the aesthetic qualities of, say, modernist and Shaker

[4] Unfinished goods in this model very much resemble the indifferent goods of Christaller's model (see page 37).

designs, mean that they are clearly not equivalent (*i. e.* substitutable) and that their markets can overlap.

Economies of Scale: In classical economics, excess profits attract the attention of competitors, driving net profit to zero, and temporary monopoly profits only emerge when technological change gives a cost-advantage to a single producer. But the spatialisation of economics complicates this process significantly since it effectively permits these profits to persist indefinitely. Lösch (1954 [1973], p.260) notes five reasons why monopoly profits can be maintained in a competitive market, but the two most interesting ones for our purposes are: when a settlement 'discontinuity' disrupts the entry of competitors because it interferes with the optimal distribution of markets between them; and when 'skilled entrepreneurs' are able to use economies of scale to price their goods (of which more later) such that marginal producers are deterred from entering the market.

In an equally counterintuitive fashion, a fall in the price of a good obviously causes the maximum area across which it can be sold to increase, and also causes the minimum area necessary for profitable operation to decrease (1954 [1973], p.174). We might expect this decrease to benefit the most efficient firms by extending their markets at the expense of their less efficient competitors. Instead, increased local demand may actually permit a new firm to enter the market at a previously unprofitable location, reducing the existing firms' markets (1954 [1973], pp.172–173). Similarly, instead of squeezing out marginal producers, increases in production costs may actually benefit less efficient producers because shipping costs become less important as a share of the final cost and reduce the advantage of the efficient firm (1954 [1973], p.175). These complex interactions mean that we cannot treat the firm in isolation (Lösch, 1954 [1973], p.8), and we should also note that these peculiar interactions between space and scale are absent from Christaller's analysis.

The Range of a Good: In a sense, changes to the cost of production or transport impact the effective density of consumers, and this is before we even consider that firms might pursue different pricing strategies to protect or extend their markets. According to Lösch there are at least three ways to price the shipping costs of a transaction: the price is negotiated on an individual and per-order basis according to volume and distance; the price is proportional to the distance shipped; and the price is based on the average shipping cost for all transactions (1954 [1973], p.139). The second option is what we would normally think of as the linear costs of transport—the further something is shipped, the more it costs us to do so—but the last option is rather interesting: it is a form of spatial subsidy in which local customers support 'exports' to more distant consumers in markets where the firm could not ordinarily compete. This subsidised shipping model is actually quite common, as anyone who has used a national postal system would know.

Conceptually, the quantity of goods that a firm can sell over a distance looks like an inverted 'cone' (Lösch, 1954 [1973], p.105) or 'funnel' (Valavanis, 1955, p.638), but one whose shape is easily distorted by infrastructure and demand (Lösch, 1954 [1973], p.114; see Figure 2.2). By freeing firms from the Central Place, Lösch enables them to experiment with different strategies for positioning the sales cone to maximum effect. So instead of locating *in* a metropolis, a firm might choose some central location *between* several of them, enabling it to compete in multiple markets simultaneously (1954 [1973], p.121). But clearly there is no one optimal strategy: a factory located at the centre of its market is closer to all of its potential consumers, but it could also potentially be undercut in a market by a competitor locating in (or closer to) one of its centres of consumption[5].

[5] On the whole, Lösch did not have much time for Hotelling's (1929) earlier work on this topic since it assumed not only that the rival's pricing was fixed, but also that locational choice was confined to just one dimension, rather than two (1954 [1973], pp.72–75).

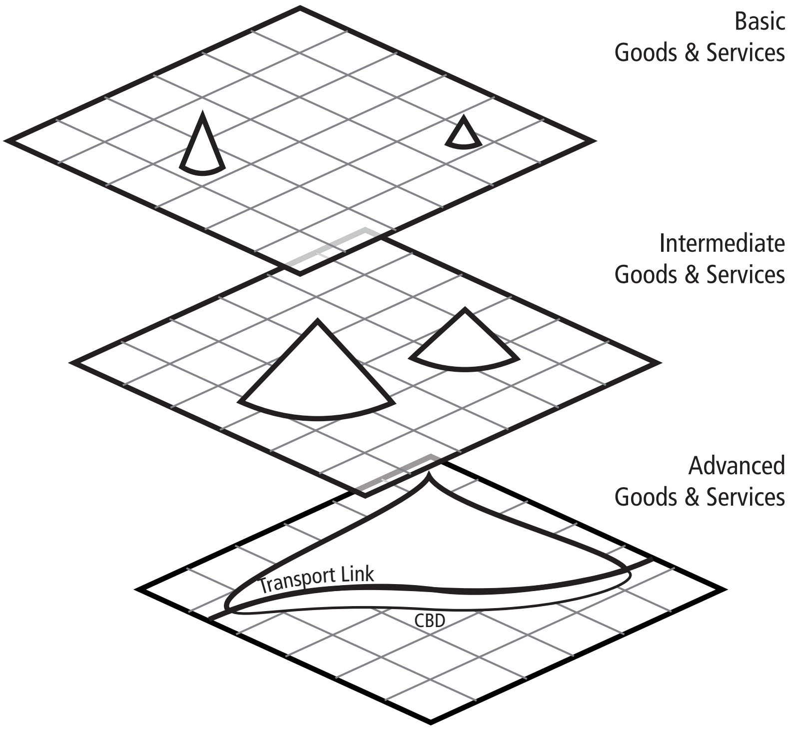


Figure 2.2: Illustration of Varying 'Cone Sizes' for Goods

Another advantage of dropping the central place as the foundation of a regional system is that we no longer need to explain the hierarchy of places with a hierarchy of production—towns of the same size can harbour different industries and fulfil different economic functions (Lösch, 1954 [1973], p.126). But this makes the ability to move goods efficiently across long distances even more important than it was for Christaller, and here Lösch edges towards an analysis that is informed by each infrastructure's unique node and link characteristics. For instance, in the case of roads there are many possible connections between any two points in the network, but in the case of container ships or planes there are much more severe constraints and much greater costs associated with the addition of new links or nodes (1954 [1973], pp.180–183). We will see why this relationship is particularly important to understanding the role of telecoms in Section 2.4 (see page 53).

Profit: Putting these elements together, we see that it is neither the location of minimum transport costs nor the point of maximum revenue that determines the location of a firm, but the place of maximal profit at each point in the supply chain (Lösch, 1954 [1973], p.27). We can use three special cases to tie together these ideas: a firm would choose the site with the lowest shipping costs only if production costs were the same everywhere and if the level of demand across space were a constant; a firm would opt for the place with the lowest production costs only if shipping costs and personal contact with customers played no role in profits; and finally, a firm that focussed on the lowest price (instead of the greatest profit) would be subject to both sets of forces simultaneously (1954 [1973], p.261).

Placing these issues in a transport context, we can see how costs filter 'backwards' from the primary market through the transport infrastructure. If we start with the net profit obtained from the final price on a shelf (whether literal or metaphorical), then at the next link back in the production chain the effective profit is the final market price *less* the distribution costs of that last link. Working back to the raw inputs, we must subtract not only each stage's costs of processing and production, but also the costs of shipping the output onwards to the next stage (1954 [1973], p.188). So an increase in transportation costs might not only cause a market to contract, but also to become more fragmented: production may not only cease to be profitable at the least connected locations (*i. e.* those with the greatest shipping costs to market), but also at marginal sites even if they are quite close to the final market (1954 [1973], p.189).

Lösch's approach highlights the fact that firms must factor in not only their own production costs, but also the way that different locations entail different transport costs depending on the available infrastructure and distances to market. For instance, in a study of containerised networks, Fowler found that the cargo from Asia tended to head towards the nearest American port: so Japanese cargo accounted for the largest volume of containers passing through the Pacific Northwest, while Chinese goods were likely to pass through Los Angeles or San Diego (2006, pp.1439–1440). For (Lösch, 1954 [1973], p.187), the existence of such large 'naturally-determined nodal points' (or, more accurately, inter-modal points) will impact the locational decisions of firms: not only are there relatively few deep harbours where bulk goods can be unloaded, but their position relative to final markets within North America is such that the destination chosen has real time and cost effects.

Agglomeration & Technology

Agglomeration: For Lösch, the clustering of firms in space does not imply—as it tends to in Christaller's model—any necessary specialisation of functions. Sometimes firms benefit from colocation with suppliers, competitors, or customers, but sometimes they just happen to have found similar advantages to a particular point in space. So, Lösch identifies four categories of propinquity: the true network, the restricted market network, the cluster, and punctiform agglomeration (see Figure 2.3). Confusingly, some of these terms are used in senses that are an almost direct contradiction to the way the same terms are used today.

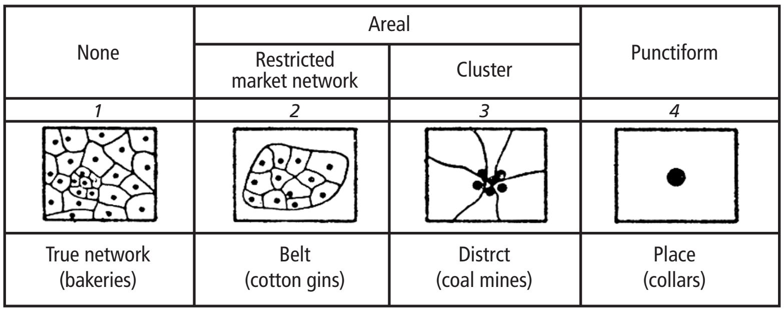


Figure 2.3: The Concentration of Locations (reprinted with permission of Elsevier from Lösch, 1954 [1973], p.11)

The 'true network' occurs when there is no advantage to spatial clustering at all. The 'restricted market network' is one in which localised advantages encourage clustering in a given region but not in any necessary proximity. The 'traditional cluster' is a configuration in which producers are clustered together spatially but operate independently of one another. And 'punctiform' (*i. e.* point) agglomeration occurs when producers derive particular benefits from proximity to one another (Lösch, 1954 [1973], pp.10–12).

Lösch argues that agglomeration would arise *even* on a perfectly featureless—*i. e.* homogeneous—plain with perfect transport as a result of the advantages offered by: number, association, and site and supply (1954 [1973], pp.69–75). 'Numbers' means the sheer concentration of firms and people in space, and more specifically the concentration of infrastructure and of highly skilled workers. 'Site and supply' refer to the natural advantages accruing to particularly well-connected locations with easy access to factors of production. In some cases the supply of a particular input is restricted—Lösch offers coal, spa towns, and universities as examples—in which case firms may find themselves more spatially constrained than normal, but dependence on a particular class of inputs does not necessarily imply dependence on a single location if there are several from which to choose (1954 [1973], p.83).

In addition, sometimes agglomeration is simply driven by the imperatives of spatial competition, such as when there is a level of local demand sufficient for multiple firms but where the transport costs from the next nearest production centre are prohibitively high. In that case it may be impossible to compete against the 'incumbent' from a distance and the only viable strategy is to locate within the same market and compete from a common location. However, as more and more firms concentrate within the agglomeration, the demand curve effectively flattens so that a firm able to undercut its competitors by just a few pennies could theoretically conquer the market (1954 [1973], pp.69–71).

Technology: As we have seen above, a lowering of transport rates will normally increase competition between firms because the distance things are shipped makes up a smaller proportion of their final cost. But the change would also tend to favour industrial concentration where the inputs or labour supply are most favourable, resulting in a shift from locations with the advantages of transit to those with the advantages of production. Vance (1970, p.133) notes that we can think about technological change in terms of whether it affects customer access or supply-of-goods access, and these are both analytical standpoints with which Lösch would have been in complete agreement.

In terms of the implications for firm location, the increased flexibility of the delivery truck over rail would favour firms that compete on the basis of production costs, and would also tend to break up agglomerations that depend solely on transport cost advantages for their continued existence (Lösch, 1954 [1973], p.23). We can see the effects of technology on transportation operating at a grand scale in today's manufacturing sector: as a share of the final cost, transportation costs are now so low that for many firms it is entirely logical to build products in China for sale in America. Technology-supported standardisation of the movement of goods mean that 'fast intermodalism'—upon which "teleservices, online shopping and JIT logistics" depend (Audirac, 2002, p.218)—has largely done away with the high cost of transshipment points associated with the pre-containerisation era (Levinson, 2006). However, as Lösch would have noted, this is not a one-way process since increases in shipping costs may also favour re-concentration: the rise in oil prices in the mid-2000s caused transport costs to soar and created incentives for firms to relocate factories to Mexico, or even back to the U.S. (Engardio, 2009).

In Lösch's analysis, the telephone and the radio act much like transportation improvements, and so encourage the break-up of agglomerations whose *raison d'être* is transportation (See: footnote in Lösch, 1954 [1973], p.115). Obviously, *The Economics of Location* predates the globalisation of services made possible by cheap international telecoms, but Lösch's treatment also seems entirely consistent with the off-shoring of services (even if the scale is rather different) to call centres: the English-speaking nations of the Caribbean tout benefits to multi-nationals that include 'abundant and inexpensive labour, low turnover and high loyalty, and under-employed but educated workers able to communicate in English' (Skinner, 2004, p.219). In fact, from a purely transport cost perspective, the question that we need to answer is not why services have left Europe and North America, but why so *few* services have done so since the cost of labour is nearly negligible and the cost of 'transport' even more so?

Spatial Implications

Lösch's analysis indicates that on a flat plain inter-firm competition would generate the characteristic hexagonal network of market areas also observed in Christaller's model (1933 [1966], p.66). But by detaching production from central places and associating it with individual firms instead, the way is cleared for the resulting distribution to become much more complex, and towns of the same size can harbour entirely different industries and fulfil entirely different economic functions (Lösch, 1954 [1973], p.126). In fact, small towns or agglomerations may be completely dependent on larger neighbours for most goods but still lie at the centre of very large market in which they are a regional or world leader (1954 [1973], p.216).

We can imagine placing three or more transparencies, each representing the unique market area pattern of a product, at random on a table. Any point on the table where the production centres of two or more layers overlap becomes a 'centre of industry'. The greater the number of overlapping centres, the greater the level of development (1954 [1973], p.124). A point on the table where a node in *every one* of the market areas overlapped would be a metropolis of sorts—a centre of production for all manner of goods and services—while the other nodes would develop in proportion to the number of market areas that are focussed on that particular point in space (see Figure 2.4).

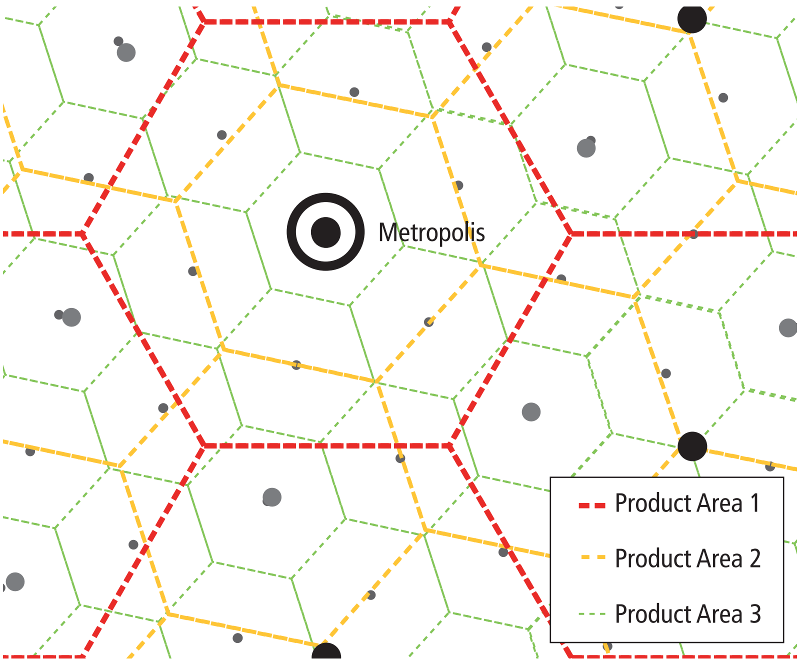
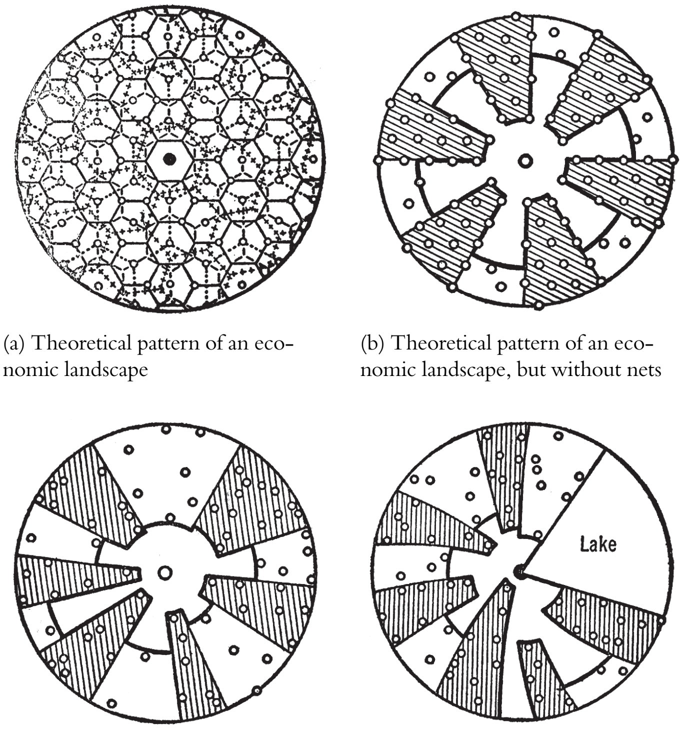


Figure 2.4: How Overlapping Market Areas may give Rise to a Metropolis

The absence of hierarchy also means the absence of a one-to-one relationship between sites of production and sites of consumption (1954 [1973], p.8). This is, at heart, the comparative advantage of being located near to a major transport node—the market is more accessible to the firm (1954 [1973], p.22). And this advantage can be compounded "where lines of communication cross (pure situation) or traffic of different sorts meet" (1954 [1973], p.83) because it increases the ease and flexibility with which the firm can access different markets. In fact, Lösch predicts that a network of settlements will emerge that is based on minimising travel distances from anywhere in the network to all available products; the result is a 'cogwheel' shape[6] that contains alternating areas of densely- and sparsely-connected settlements as shown in Figure 2.5[7].



(a) Theoretical pattern of an economic landscape

(b) Theoretical pattern of an economic landscape, but without nets

(c) Indianapolis and environs within a radius of 60 mi.

(d) Toledo and environs within a radius of 60 mi.

Figure 2.5: How a 'Cogwheel' Shape Emerges from Market Networks (reprinted with permission of Elsevier from Lösch, 1954 [1973], p.125)

What sets Lösch's analysis apart from more simplistic treatments is his acknowledgement of the practical dimension: across larger distances other factors may intervene to create constraints on market areas. For instance, a 'local' entrepreneur may often have a better sense of the market in the culture or nation of which he is a native, and so national borders will often constitute market borders as well (Lösch, 1954 [1973], p.191). This border can be artificially maintained as well: although it is not an entirely traditional trade barrier, Canada's requirement for bilingual labelling on all packaging (even for goods not destined for sale in Quebec) is clearly designed to limit market access for American producers and create a 'captive' minimum market for Canadian firms (Export.gov, 2009).

Summary

With Lösch's model we are moving from a structured, hierarchical world to one in which the location of firms is mutually determined by relationships of collaboration and competition (1954 [1973], p.8). What makes a particular location or town attractive will differ from firm to firm, and so an areas's 'centrality' in terms of its diversity and output is no predictor of where a company will ultimately locate since local production factors will have different degrees of significance for different industries (1954 [1973], p.81). Lösch is on the cusp of grasping

[6] The fuller explanation of this result is that we begin by placing each product's hexagonal market map such that they all have one market centre in common (the metropolis). We then rotate the maps so that as many *other* locations as possible coincide as well, with the idea that the maximum number of purchases can now be made at one local location and the cost of travel to and from that location is at minimum. The updated underlying assumption—that transport infrastructures tend to evolve towards a balanced global minimum covering cost, efficiency, and fault tolerance—has been put to the test using slime moulds (and computer simulations of their behaviour) for the Tokyo rail system (Tero et al., 2010), and the British motorway network in the entertainingly titled *Road planning with slime mould: If Physarum built motorways it would route M6/M74 through Newcastle* (Adamatzky and Jones, 2009)

[7] The data for the maps in Figures 2.5c and 2.5d seems to have been taken from (Ambrosius, 1881 [1930], p.198).

the role of complexity and self-organisation—of the sort captured by contemporary developments in Agent-Based Models in the complexity sciences—in regional economic development, but he shies away from the 'chaotic' elements, deeming them "insignificant" (1954 [1973], p.219).

Lösch emphasises that there are in fact four categories of economic costs connected to distance, of which transport is only one; the other three are: time costs, selling costs, and business risks (Lösch, 1954 [1973], p.212). In Chapter 3, I will argue that the idea that risk—resulting from a lack of reliable information about distant markets—increases with distance is vital to understanding the reason that some industries (finance, for instance) continue to cluster in particularly high concentrations in just a few parts of the world. We will see that the price of 'doing business' is compounded by distance-related costs of acquiring and exploiting knowledge from distant markets (whether this is defined in terms of geography or culture) and that these definitely do not increase linearly with distance.

Of course, Lösch's model does not fundamentally negate the importance assigned in Christaller's work to two key ideas: that the concentration of demand in cities acts as a stimulant to development, and that places that act as nodes in a wide range of short- and long-distance transport networks are likely to attract firms. Nor have these benefits disappeared with the growth of multi-national enterprises (MNEs) and the Internet: a recent publication from Britain's National Endowment for Science, Technology and the Art (NESTA) notes that "specialised or niche market preferences and tastes can often be provided for on a profitable basis from a city, as the market is of sufficient size to make this economically viable" (Athey et al., 2007, p.20).

But, the NESTA report goes on to say, "…case studies show that most innovative businesses make use of urban connectivity to operate in larger national and global arenas" (Athey et al., 2007, p.27). So cities are important to new and innovative firms not only because they constitute large, ready-made markets for specialised services, but also because their long-distance transport networks give firms a platform for accessing remote markets for goods and services that could not be profitably serviced from a less well-connected region. In short: "urban areas still possess a major advantage over non-urban areas in the thickness and density of their communication infrastructures and ICT networks" (2007, p.17).

The final point to note here is that Lösch's analysis shows that a lessening of transport costs creates a freedom to focus on production or labour costs, while an increase in transport costs as a share of total costs will constrain that freedom in important ways. In other words, as a factor of production becomes relatively less expensive or more accessible, it tends to count for less in a firm's spatial strategy. This relativity is an absolutely crucial point to keep in mind in the following chapters, and it extends not only to these three broad categories but also down, as the following section will show, to the relative flexibility of factors within each category.

2.4 Theory of Network Flexibility

What this review has shown so far is that regional and urban economic development is intimately connected to the availability of transport and communications infrastructure. And although both Christaller (1933 [1966]) and Lösch (1954 [1973]) incorporated aspects of infrastructure change, they did not explore in any depth how the usage of new infrastructures might be moderated by the ones already in place. Firms may opt for anything between *substitution*, in which the use of one network directly replaces the use of another, to *complementarity*, in which the use of both networks increases in parallel, but how do we determine which firm will pursue which strategy?

Furthermore, traditional network science, which has its roots in physics and sociology, tends to focus on the importance of network nodes—people, particles, and ports, for instance—while treating the connections between them in a fairly unproblematic way. However, in the case of infrastructure, the links are affected by the decisions of 'agents'—shippers, commuters, and business travellers—able to make real choices about mode, and so the "focus on nodes has limited the degree to which these researchers have been successful in understanding the relations between them" (Fowler, 2006, p.1429).

It also seems that we need to explore the concept of 'cost' in more depth because, as we have seen in Christaller and Lösch, this is the key to understanding the likely impacts of telecommunications on other infrastructure. As Graham (1997, p.112) notes: "treating telecoms networks as 'distance shrinking' or 'electronic highways' is to apply the same transportation-led metaphor—'friction' is not reduced, it is completely annihilated by telecoms because 10km and 10,000km are equivalent." So from an economic standpoint, the cost of telecommunications relative to other modes of interaction is such that it is strange to imagine people travelling at all. To answer this question will take the better part of two chapters, but this section begins to frame an answer by focussing on the concept of flexibility.

Simplifying Assumptions

In order to compare telecommunications with other forms of infrastructure, we need some common set of metrics by which to analyse radically different methods of 'moving' goods and services around the globe. In fact, it seems that the best way to meet this challenge is not to think of anything moving at all, but rather to frame the problem in terms of communication in which the exchange of products, people, and bits represent a kind of information flow. This translation allows us to interpret the issue in informational and organisational terms, and to turn to literature from these fields in order to begin addressing an issue that is fundamental to the relationship between direct and digital communications.

Fulk and DeSanctis (1995, p.338; see also Panteli and Dibben, 2001) propose five ways in which the changes in communications technologies are affecting organisational forms, these are: increasing speed;

declining cost; rising bandwidth; expanding connectivity; and the increasing integration of communication and computing technologies. Fulk and DeSanctis' analysis is obviously oriented towards telecommunications, but I would propose that this framework can also be applied to to the study of physical infrastructure as well. Clearly, it is a critical assumption here that these five dimensions describe all (or least most) of the relevant features of infrastructure, and that we can use them to compare transport and telecoms infrastructure along a similar scale.

Without this approach, we must treat the two sets of infrastructures separately and cannot draw any meaningful conclusions. In effect, if we focus on transport to the exclusion of telecoms then we would be excluding what is for most firms and households the defining innovation of the second half of the 20th Century. Conversely, if we ignore the dependencies that we still have on transport infrastructure then we slip into the mindset of the technological determinists who expected that simply because a technology that transcends space exists, then space is largely irrelevant. Deriving a set of dimensions across which all such infrastructure can be compared, no matter how impressionistic the criteria, is therefore an important first step in this analysis.

Monetary Cost: Outside the worlds of economists and planners, *most* people frame their thoughts on cost in terms of monetary costs. There is clear evidence that the monetary cost of both communication and transport are falling in the long term for both suppliers and consumers (Fulk and DeSanctis, 1995, p.338; Glaeser, 2006, p.313). The reduced cost of telecommunications is the more obvious: Hamill (2000, p.59) reports that by 1995 the cost of a three minute trans-Atlantic call has fallen from $250 in 1930 to less than a $1 in 1990 dollars. But the changes in air travel are no less spectacular: a blogger for the *New York Times* reports finding a one-way ticket from Shannon to New York dating from 1946 at a jumble sale: its face value in today's dollars is well over $3,000 (Smith, 2007). And BBC Four (2009a) notes that by the 1950s, although the cost of a one-way ticket between London and New York had fallen to £173 (£3,000 today) this was at a time when the average *weekly* income was £12 (£210 today).

In the case of telecommunications, wholesale rates are plummeting even more rapidly than they have for other infrastructure: in just three years the median price for leased bandwidth connecting cities such as Miami and Sao Paulo, or Los Angeles and Tokyo fell 75%, from nearly $80,000 per month to 'just' $20,000 per month for stm-1 capacity (PriMetrica, 2006b)[8]. Figure 2.6 (on page 55) shows some similar declines for retail users placing international calls from the U.K.The magnitude of these drops has given license for people to predict that communications will eventually become costless; however, this notion shows scant regard for the fact that cheap is not free, and it most certainly will not mean free within the relevant timeframe for most policy- and plan-making. Moreover, Lösch's analysis should have alerted us to the importance of *relative* costs, and to changes in the relationships between costs, as well as to the differential impacts of various pricing

[8] stm stands for Synchronous Transfer Module; the '1' is an increment of 155.52 Mbps, where *n* currently ranges up to 64: 64 * 155.52 = 9.953 Gbps for STM-64 (Myles, 2009)

schemes being made possible through ICT integration and data analysis: everything from roads and rail to telecommunications can now be billed on a fixed-charge, per-use, or peak-use basis.

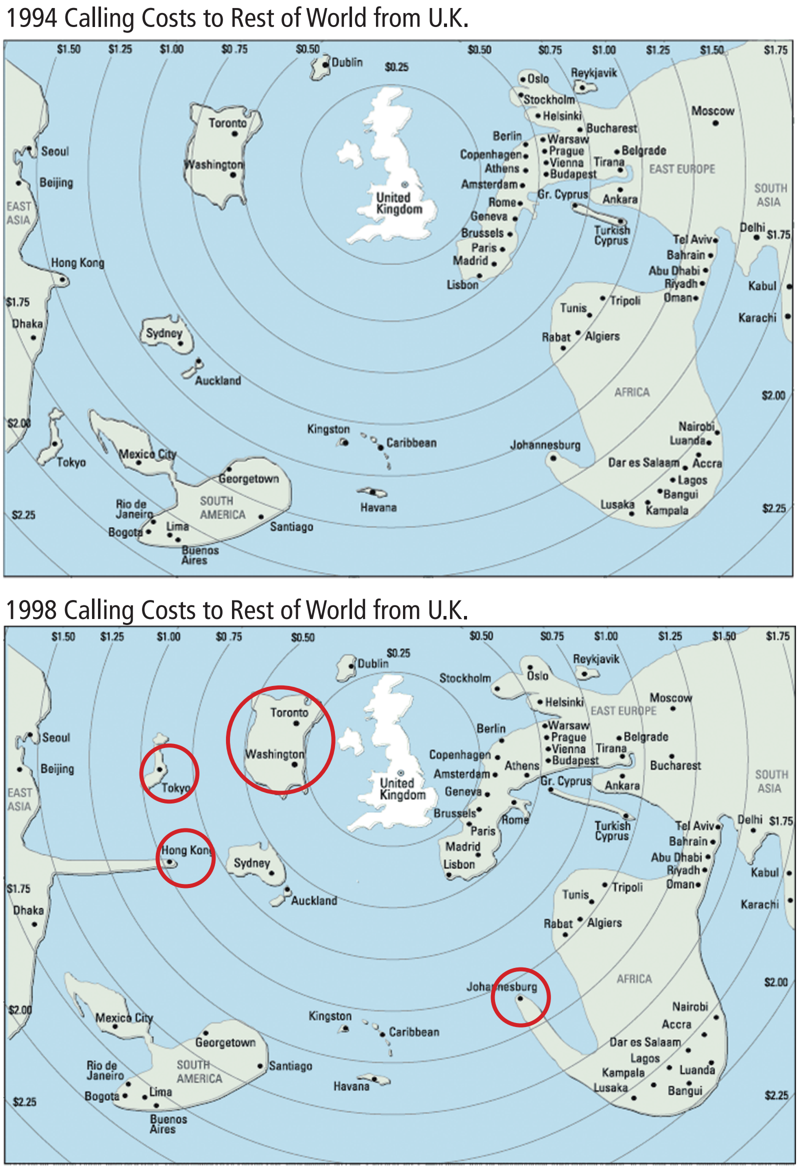


Figure 2.6: Decline in Peak International Calling Rates (1994 & 1998) (PriMetrica, 2002a,b; reproduced with permission of TeleGeography/PriMetrica)

The other issue we need to consider is that these various infrastructures may not change uniformly over time: one may become faster, while another becomes cheaper or more comfortable. This is something that the traditional Cost-Benefit Analysis (CBA) for transport projects has tended to overlook because of its focus on easily-measured direct and indirect costs such as: construction, travel time reductions, and ongoing costs to users (Elhorst and Oosterhaven, 2008, p.66). New approaches have broadened this method to include factors such as journey ambience and reliability (Department for Transport, 2004, pp.10–12), but it is still difficult to to know how to place a monetary value on what Aberlado Carrillo, Director General of Spain's high-speed train service, sees as the Ave's principal competitive advantage over the plane on the Barcelona/Madrid route: "Time spent in a train is time won, while in a plane it is wasted. In a train you can work, read, talk, use the internet, eat, or simply relax and enjoy the journey. With a plane, the only objective is to arrive" (Hamilos, 2008).

For privately-funded networks there are clear incentives to focus provision on those with the greatest ability to pay for services. Figure 2.6 also shows that changes to the cost of calling abroad from the U.K. between 1994 and 1998 vary dramatically: the decline is far from global. So although nowhere seems to have become more expensive, there are many cities in Africa and Asia that remain just as inaccessible from a telecommunications standpoint as they were four years previously. In contrast, note how the most visible improvements are clearly linked to what the Globalisation and World Cities group (GAWC) term the 'world cites' such as Tokyo, Johannesburg, and Hong Kong (cf. Taylor et al., 2001; Taylor and Walker, 2001; Taylor, 2005). So from a communications standpoint the 'digital divide'—which we can read here as the *relative* difference in cost—widened during those four years even though no region became more expensive to reach.

Speed: The speed of a network is typically taken to be the single most important factor for business adoption because of its effects on the ability of a firm to coordinate activity across space and to supply it with the physical and informational inputs that it needs to complete. For example, the speed with which information can spread via e-mail clearly marks a radical shift in our communicative ability and, accordingly, e-mail was reckoned to have induced profound changes in the way that we live and work (Cairncross, 1997, pp.104–105). Similarly, digital videoconferencing has been put forward as a replacement for long-distance business travel since it enables participants to meet 'face-to-face' at short notice without ever leaving the office.

However, a focus on speed overlooks the less visible role of latency—the delay between a stimulus (*e.g.* a request for information) and a response—as a network characteristic. For instance, dial-up and satellite broadband networks used by households and businesses in remote areas provide very different types of performance both in terms of speed *and* latency: dial-up networks typically have low speeds and low latencies, while satellite connections are the opposite. So although these two infrastructures can technically provide access to the same content, depending on the characteristics required by the user one or the other channel may be entirely unacceptable: satellite broadband would be appropriate for domestic users accessing media files but not for business applications requiring real-time communications. It is also worth noting that in some cases latency may be both deliberate and desirable: voicemail and post-it notes may have high latencies, but they enable us to communicate asynchronously and unobtrusively (Graham, 2004, p.123). The set of relationships outlined in Table 2.2 helps us to see the myriad of ways in which different bandwidths and latencies can be used to optimise the communications process.

Table 2.2: Advantages & Disadvantages of Communications Alternatives (after Mitchell, 2004, p.125)

	Synchronous	Asynchronous
Presence	Intense, multimodal, immediate feedback, high transportation costs, requires coordination, requires full attention	Limited by storage and playback capacities, no immediate feedback, no reduction in transport costs, no reduction in space costs, no need to coordinate, may allow some division of attention
Telepresence	Limited by bandwidth and interface capabilities, retains immediate feedback, reduces transport costs, requires coordination, may allow some division of attention	Limited by storage, bandwidth and interface capabilities, no immediate feedback, reduces space costs, no need to coordinate, allows multiple activities and transactions in parallel

On physical networks, latency also plays an important role, though to my knowledge this has been less studied in the transportation literature. For instance, Feitelson and Salomon (2000, p.475) wonder whether HSR will be able to compete effectively with regional air travel; but for users facing the ongoing fallout of terror attacks on air infrastructure, along with the increasing congestion of airports, the answer is a rather resounding 'yes'. Hall (2009, p.813) indicates that "experience in Europe and Japan teaches that these [HSR] trains will take about 80–90% of traffic up to about 500 kilometres and about 50% up to about 800 kilometres." So even as the monetary cost of air travel has fallen dramatically, for many people its full economic costs have risen, which is why Eurostar estimated that by 2006 it was carrying more than 60% of traffic to Paris and Brussels (Department for Transport, 2006)[9]. Ultimately, with a sustained speed of 350 kph, continued lower latencies (*i.e.* shorter check-in times) and greater comfort (*i.e.* better food and on-board WiFi), HSR should be able to compete successfully with aviation over travel times up to about four hours, representing a distance of about 1,000km (Hall, 2007a, p.429).

[9] And we can expect this figure to rise with ongoing improvements to the network as well as the addition of unified ticketing and scheduling through to destinations in Holland and Germany (Hall, 2007a).

Beyond this 1,000km threshold, however, the speed of air travel compensates for its higher latencies, which is why only the dedicated rail buff—or the curious—would consider travel from Britain to Spain by rail (McKie, 2008). But it is clear that further changes in either speed or latency may again alter the cost-benefit calculation employed by travellers. More broadly, with the notable exception of telecommunications, for most networks it seems that the higher the speed of movement the greater the latency due to the coordination requirements of the system. However, given that telecoms evades this historical trade-off, we need to ask why, for instance, businesses haven't dropped time- and money-intensive international air travel entirely in favour of digital collaboration? This issue is a central consideration of the rest of this work.

BANDWIDTH: Bandwidth is the overall 'data capacity' of the network over some arbitrary period of time. Although bandwidth is obviously based on the interaction between speed and latency, the implications are quite nuanced: on a 1Mbps broadband connection, a DVD-quality film of about 5GB would take over 11 hours to transfer electronically, but copying the film to a recordable DVD and delivering it by hand might take less than an hour, yielding an effective bandwidth of over 11Mbps. So although the latency of this 'sneakernet' (Wikipedia, 2004) is quite high, its bandwidth is nonetheless also substantial since the entire film is delivered in an elapsed time of just one hour.

The interplay between competing networks at the level of bandwidth is encapsulated in Tanenbaum's admonition that we should "[never] underestimate the bandwidth of a station wagon full of tapes hurtling down the highway" (1996, p.91). The challenge for more complex comparisons between classes of infrastructure is that there are few situations in which we can directly compare the movement of goods, bits, and people to establish which channel has the higher bandwidth. For instance, research in the 1960s suggested that less than 35% of the informational content of a conversation is conveyed orally, and that the rest is communicated "with facial expressions and body language" (Crockett, 2007).

Firms have long been aware of the limits of voice-only teleconferences, and so companies such as HewlettPackard and Cisco have developed and deployed video conferencing technologies that they claim are able to mimic physical copresence with sufficient fidelity to offer an alternative to business travel (cf. Economist, 2007a, 2009b). The cost of these 'telepresence' rooms starts at $300,000 and entails an additional monthly contract cost of nearly $20,000 (Economist, 2007a). Moreover, the capacity required to support these technologies is not universally available: compare in Figure 2.7 the bandwidth between the U.S., Canada, and Europe with that available for conversations with South America or, worse still, Africa.

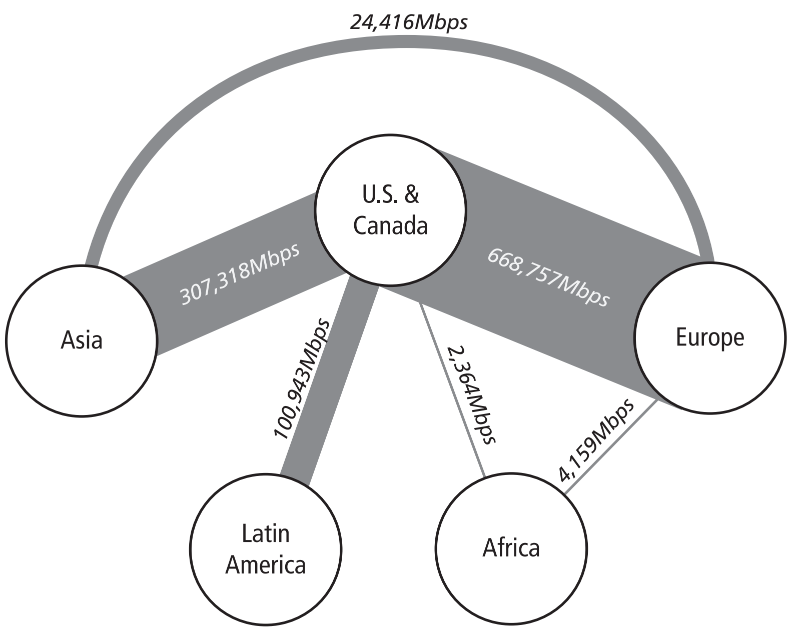


Figure 2.7: Inter-continental Bandwidth Capacity (PriMetrica, 2005; reproduced with permission of TeleGeography/PriMetrica)

What both the research and the sheer cost of telepresence facilities suggest is that face-to-face interaction has a real, but possibly unquantifiable, 'bandwidth' that is much, much higher than the equivalent transcription of a conversation. This idea will be explored in more depth in Chapter 5, but it is clearly going to be of interest whether corporate travel is, in effect, a method of transferring business expertise and experience across long distances. In short, can we consider people to be 'packets' in a massive communications network operated over transportation infrastructure?

Regardless of the answer to this question, using the concept of bandwidth in this broader sense enables us to consider some different performance characteristics of networks: high speed rail and air travel are able to process larger numbers of people at once through specially-designed 'nodes', but their overall capacity pales in comparison with the roadways. And while both road and telecoms networks have an enormous overall capacity, this does not necessarily translate into an equally enormous bandwidth between any two points in space because of congestion and their limited capacity to absorb data at each end-point.

Connectivity: We can partially address this issue with the concept of connectivity, which points to the value of adding new nodes to a network. On digital networks—as well as retail and social networking sites—this idea has often been understood in terms of 'Metcalfe's Law' (Hantman, 2006), which states that the value of a communications network is proportional to the square of the number of compatibly communicating devices or users (Simeonov, 2006). The empirical observation underlying this claim is that while one phone is useless, and two phones have just one possible connection, eight phones have twenty-eight possible links, and twenty phones have 190. Rather than growing linearly, the potential to reach out explodes exponentially and this 'network effect' increases its attractiveness to others not yet part of the network.

Another way to think about connectivity is through the question: can I reach 'there' from 'here'? In other words, how easy is it to move information in some form between any two nodes? The answer clearly depends on the type of network. With certain important caveats, in the digital realm every node in the network is equally accessible to every other node, but in aviation networks some global transportation hubs are reachable in just one or two hops from anywhere in the world, whereas smaller airports may well be as many as six jumps away from a local airport on another continent, and the capacity between any two points varies dramatically (see Figure 2.8[10]). Quite simply, nodes in some networks are more 'connected' or 'linked in' than others.

[10] "The size of the nodes varies with the total number of incoming or outgoing passengers; the size of the edges varies with the number of passengers flying between two cities. For reasons of clarity, only the most important links are shown" (Derudder and Witlox, 2005, p.2381). I have added colouring to further distinguish the groupings.

Integration: In Fulk and DeSanctis' typology, integration is a measure of the extent to which telecommunications have moved beyond a "purely connective function" to actually merge with computing technologies as a seamless 'whole' (1995, p.338). One contemporary example of successful integration by this metric (especially in combi-

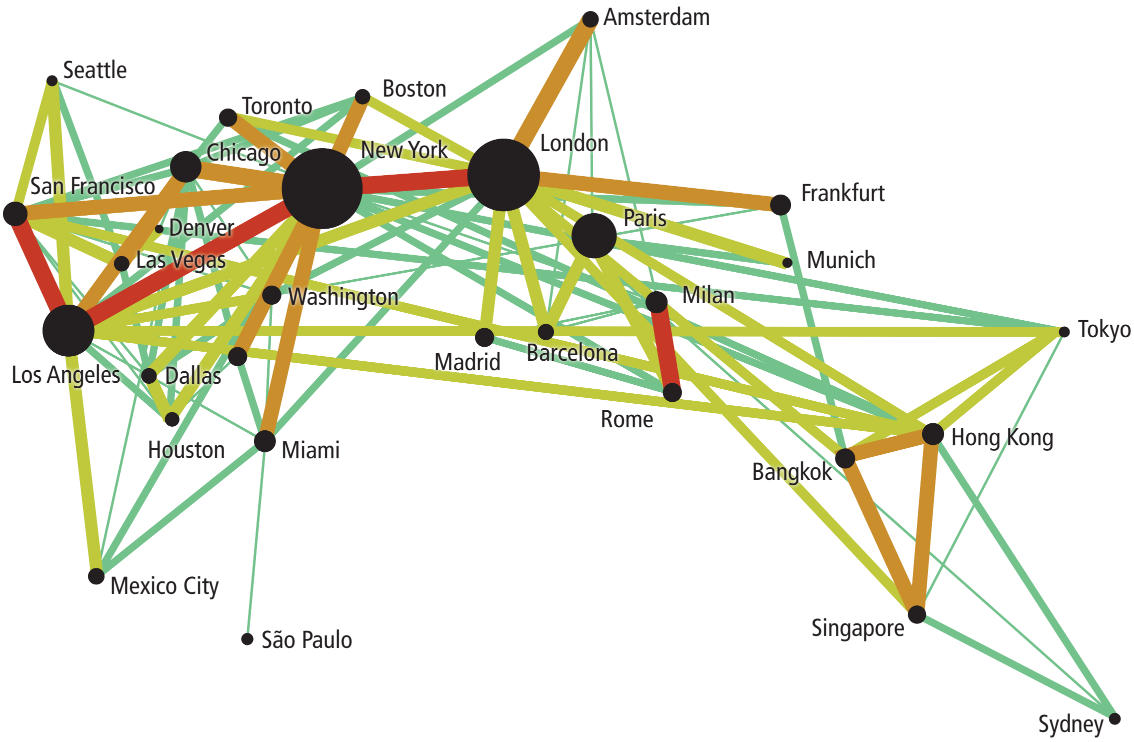


Figure 2.8: Largest Nodes & Links in the Air Travel Network (Derudder and Witlox, 2005, p.2384; reproduced with permission of the authors)

nation with good design and relative affordability) would be the impact of the iPhone on mobile network data usage in the U.S. and U.K., where it has caused the usage of data-driven services to soar (GigaOm, 2009). However, we should also bear in mind that for much of the past fifty years the integration of telecommunications and computation has been crucial "…in underpinning new ways of organising and managing physical flows of goods and physical retailing spaces" (Graham and Marvin, 1996, pp.155–156).

In this broader view, the linkage between computational and communicational power as applied to transport infrastructure is revolutionary. For instance, Intelligent Transportation Systems (ITS) point the way to a future of sophisticated real-time demand management in which infrastructure usage is coordinated around some optimal state of utilisation and flow. In a sense, the integration of ITS enables us to manipulate the economic cost of movement so as to deliver some desired balance of benefits to users; however, for this degree of coordination to emerge we first need to incorporate networking capability and a high level of embedded 'intelligence'.

For the wireline and wireless telecoms services these requirements are already achieved: even the most basic 'smart' mobile phone is already functionally indistinguishable from a networked computer, and there are now vanishingly few phones available for purchase in OECD countries that would not count as such. Advances in check-in technology mean that mobile phones are already replacing e-tickets (British Airways, 2010), but for more complex systems this level of integration may still be far off: attempts to define a common rail signalling system for European trains have been mired in the existence of twenty divergent national standards (Wright, 2008a), causing the French operator SNCF to estimate costs of up to € 2 billion for fitting its TGV trains with the correct equipment (Wright, 2008b). Until the integration issues are resolved, it is hard to see how high-speed rail will be able to compete with planes over greater distances than they do today, but the potential is clearly there.

Convenience: Convenience incorporates factors such as frequency (*how many times per hour or day can I access the service?*), availability (*how far must I travel to access the service?*) and comfort (*how pleasant is use of the service?*). Clearly, convenience is very much 'in the eye of the beholder' since there are certainly people who find the ability to be reached by mobile phone or Blackberry while on holiday a gross inconvenience. And to some extent, convenience could subsume some of the other factors presented here, but I think it important to distinguish between characteristics of the network itself and the perceptions of the people using it.

For instance, the road network is accessible almost anywhere and with my own car the scheduling of departures is entirely up to me. This is clearly a form of convenience inherent in the network itself and largely separate from the specific appeal of travel by car. The profusion of communications and audio-visual gadgets in vehicles suggests that the level of 'comfort' inside the car is rising rapidly and that private vehicles increasingly resemble personal 'mobility cocoons' rather than modes of transport alone (Sheller, 2004, p.44). The experience of travel is being impacted by the complementarity between travel and telecommunications, and mobile telecommunications is particularly radical in its effect on the inconvenience of being 'out' for most travellers.

We are so attached to our mobile devices that it is becoming difficult to recall the inconvenience cost of coordination in the 'pre-mobile days'[11]. Today, of course, we can read email, play video games, and instant message while *en route*[12], and it is no longer the case (if it ever was) that 'getting there' is the only function of the journey (Urry, 2006, p.360). Lyons and Urry note that the blurring of the boundaries between 'travel' and 'activity' time by ICT may actually encourage people to travel still more by reducing the perceived inconvenience of travel, and ask: "to what extent are ICTs providing *substitutes* for use of travel time and to what extent are they providing *enhancements*?" (emphasis in original, 2005, p.267)

[11] However, the transition period at the end of the 20th Century exposed our awareness of this cost, and one traveller with a new mobile phone was heard to ask her interlocutor: "Oh, but how did you find me?" (Anonymous, 2010)

[12] On a personal note, in 2008 I had the experience of participating in a Skype conference call from a bus in rural Estonia—the bus provided a 3G network link via on-board WiFi, and Estonia has one of the most extensive high-speed mobile networks of any country in the world.

Clearly, the convenience of a network is open to manipulation by its operators so as to provide apparent benefits to users. For instance, business-only airlines such as Eos and SilverJet touted their low check-in times and business-friendly environments, forcing the flag carriers to lower their fares and highlight the benefits of their mileage rewards and upgrade programs. The collapse of the business-only airlines in 2008 appears to owe more to rising fuel costs, an economic downturn, and the credit crunch that to any underlying failure of the model itself (Russell and Blackden, 2008) or of its appeal to the 'kinetic elite' (Hannam et al., 2006). Indeed, it will be interesting to see how well British Airways' entry into this now empty market fares—departing and arriving from City Airport eliminates travel to and from Heathrow, but it comes at the price of a jet that requires refuelling in Ireland and BA seems to counting on the added convenience of clearing U.S. customs in Shannon as a sufficient incentive to make this layover attractive.

Table 2.3: Aspects of Network Usage

Dimension	Motorised Transport		Rail Transport			Aviation		Telecoms	
	Roads	Highways	Metro	Suburban and Inter-city	High-speed	International	Domestic/Regional	Fixed	Mobile
Speed	○○	◒	○	◒	●	●	●	●●	●●
Cost	○○	◒	○○	◒	●	●●	●	○○	○
Convenience	●●	●	◒	◒	○	○○	○○	●	●●
Bandwidth	●●	●	●●	●	●	●	●	○○	○○
Connectivity	●	◒	○	○	○○	○○	○○	●●	●●
Integration	○	○	○	◒	●	●	◒	●●	●●

○○ = Very Low ○ = Low ◒ = Medium ● = High ●● = Very High

SUMMARY: What all of these issues point towards is the idea that determining the 'cost' of a network is a complex process, subject to a range of important and, often, subjective factors. We may anticipate that users will select a particular network or network-supplier based on a perception of cost that is actually a sophisticated evaluation of the optimal set of features required and of the trade-offs between them: there are those who refuse to fly economy even though the per-mileage cost is far lower, just as there are those who refuse to take a train even though the drive leaves them with less time for thinking, doing work, or napping. Within these constraints, Table 2.3 attempts to summarise the findings so far.

Network Flexibility

We have approached networks thus far solely in terms of their capacity to move 'packets' between nodes, as if the nature and location of the links between them were irrelevant, but as Fowler points out this is clearly not the case (2006, p.1429). Consequently, at the very least we need to factor in not only the topology of the network (its basic layout) but also its flexibility (the extent to which its operation and growth are constrained in time and space). This section on flexibility is anchored in Feitelson and Salomon's (2000) argument that the flexibility of infrastructure networks can be described in three dimensions: node, link, and time.

Topology: A proper discussion of network topology is beyond the scope of this dissertation, but we can sketch in some of the basic features of the relationships between nodes and links in networks (or 'graphs' as they are known in mathematics) using three basic characteristics: the shortest path, the clustering coefficient, and modularity. As its name suggests, the shortest path is simply a measure of how many links must be traversed to get from a point A to a point B and, in aggregate, this measure can give a sense of how well-connected parts of the network are to one another. The clustering coefficient measures the existence of triads in a network: if point B is connected to points A and C, then what is the probability that points A and C are *also* connected? Finally, modularity gives us a sense of whether the level of interconnection is global (everything is connected to everything else) or local (smaller parts of the network are well-connected, but there are only a small number of connections between networks at larger scales).

The reason these concepts matter is that "while infrastructure-specific aspects of a network can cause networks with high graph-theoretic properties to perform poorly, few networks with poor graph-theoretic properties can perform well!" (Gorman and Malecki, 2000, p.128) These abstract descriptions of networks can have significant real-world implications: Gorman and Malecki (2000, p.125) note that America's Frontier Telecommunications built a 'fully connected and redundant network' (*i.e.* one with a low shortest path, high clustering coefficient, and low modularity) but failed to factor in the costs of upgrading this network over time. Instead of upgrading a few key links, Frontier had inadvertently committed to upgrading its entire network for each new generation of technology. In a different way, prior to its acquisition of MCI's backbone, C&W's hierarchical, star-shaped network increased the risk of a single point-of-failure damaging the entire network's performance (see Figure 2.9).

The existence of key nodes in an otherwise largely uniform network is what creates the 'small world' phenomenon. Small world networks can be characterised by a power law in the distribution of links: most nodes have very few links, a minority have multiple links, and some tiny number of nodes are extraordinarily well-connected (Barabási, 2003, p.71). Townsend (2001, p.43) found that just seven metro areas

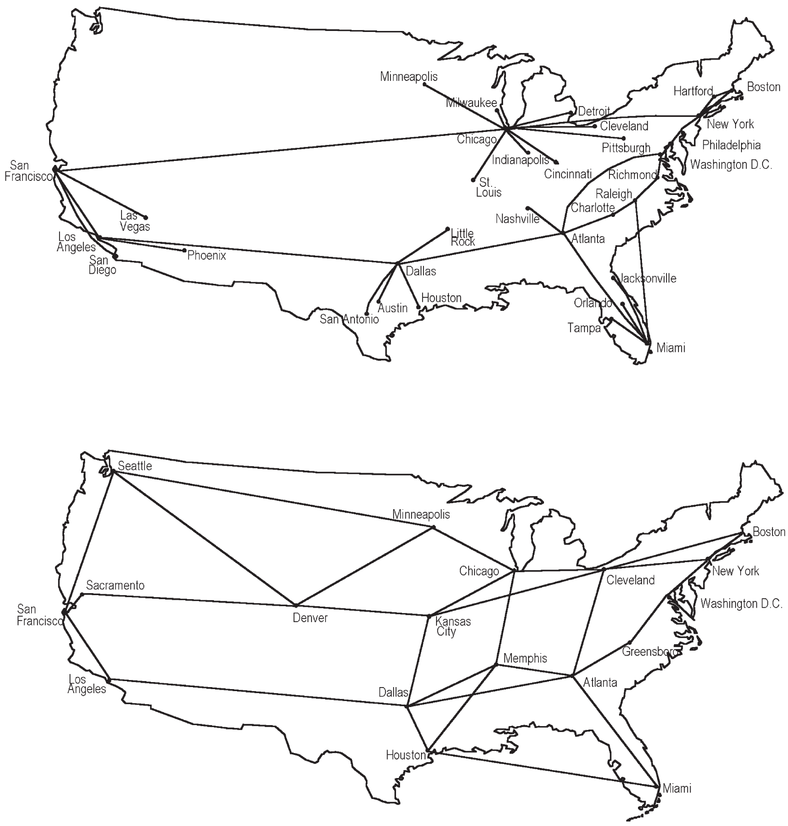


Figure 2.9: Cable & Wireless U.S. Internet backbone network before (top) and after (bottom) acquisition of MCI backbone network (Gorman and Malecki, 2000, p.130; reproduced with permission of Sage Publications)

functioned as regional nodes for America's Internet backbone networks, and that the smallest of these seven still had twice the capacity of the next-largest node (2001, p.47). This configuration is extremely efficient in terms of routing packets to as many destinations as possible in as few steps at possible, and it turns out that many transport networks also have small world characteristics, especially when we consider travel across multiple modes (Latora and Marchiori, 2002). But the concentration of traffic at just a few nodes also reduces fault tolerance if they begin to fail in a non-random manner (*i. e.* because they are congested, targeted in attacks, etc.). Figure 2.9 also illustrates how changes to a backbone network can radically alter its connectivity and resilience.

The hub-and-spoke structure of airline operations is another small world network and is the result of what Barabási terms 'preferential attachment' (2003, p.88): as more flights stop in New York, it becomes more attractive for other flights to *also* stop in New York because that is the best way to shorten the number of hops between any two randomly-selected nodes in the flight network (see Figure 2.8 on page 60). Consequently, the concentration of activity at the area's three main airports (John F. Kennedy, La Guardia, and Newark)[13] is out of all proportion to the number of people wishing to travel to and from this region alone. But it is in part the global efficiency of routing people through a small number of hubs that has enabled international passenger numbers to rise from just 25 million in 1950 to more than 700 mil-

[13] And this number does not include a host of lesser airports, some of which (Long Island and White Plains) are coming into increasing use by low-cost domestic carriers as an alternative to the main hubs.

lion today (Sheller and Urry, 2006, p.207). However, the eruption of Eyjafjallajökull in Iceland demonstrates just how quickly non-random failures can have dramatic knock-on effects on the rest of the network, and so this network efficiency comes at a price (cf. O'Brien, 2010).

Node Flexibility: We can think of nodes as the points where packets, be they human beings, physical goods, or ephemeral signals enter, leave, or are relayed through the network. So nodal flexibility is the ease with which these points can be added to the system. According to Feitelson and Salomon, flexibility "can be measured… by the time it takes to plan, approve and implement the development of a node and the cost of such development. From a network perspective this cost is the marginal cost of expanding the network by one node" (2000, p.463).

Some of the other parameters for nodal flexibility identified by Feitelson and Salomon include: the physical size of a node; externalities such as noise or other types of environmental impact; interface requirements to other networks such as rail connections or parking lots at the airport; and technical requirements such as runway length (2000, pp.464–465). The more specific and rigorous the needs, the fewer the locations that will be able to meet the requirements. Conversely, the more readily nodes can be added, the better the system can respond to shifting demands for access.

In real terms, although the intercontinental air traffic passenger network is efficient, it is nonetheless deeply inflexible because of the difficulty with which new airports can be built. Global hubs such as New York's JFK and London's Heathrow are less flexible still because of their enormous technical and infrastructural requirements and the externalities that their operations produce—Heathrow alone employs 70,000 workers, making it the largest employer by location in all of Britain (BBC Four, 2009a). For some businesses with very specific transport needs, the hub-and-spoke system's inflexibility imposes such high economic costs that the shift to the fractional ownership of corporate jets may actually be an entirely logical choice.

Link Flexibility: Predictably, link flexibility is a measure of how easily new connections between nodes can be added and of how many possible routes connect any two nodes in the network, and it is defined as: "the number of available options to use alternative links for movement between nodes, and thus the level of network reliability" (Feitelson and Salomon, 2000, p.464). So the more easily new links can be added or existing links can be upgraded, then the better a network can respond to changes in demand or to failures at a given node or link. In the case of infrastructure networks, links are clearly not abstract concepts and so link flexibility directly affects connectivity.

Criteria for assessing link flexibility include: link requirements such as the engineering standards on high-speed rail; link externalities such as the space and visual impact of rights-of-way; traffic externalities which impose restrictions on operation due to noise and pollution; and complementary infrastructure requirements to enable use of the link (2000, pp.464–465). For instance, it has been found that houses 250m to 500m from rail lines sell for between 2% and 5% less than equivalent homes further from the tracks (Bruinsma, 2009, p.117) and this is purely the result of link externalities[14].

This finding also helps to emphasise that proximity to links does not imply bi-directional or reciprocal connectivity: a house's proximity to a rail line does not in some way improve its occupants' access to rail infrastructure, and in a similar way air travel access requires ground transport but the converse is not true (Feitelson and Salomon, 2000, p.465). So whereas the air network is relatively flexible in terms of the possible links between airports (with some exceptions, see Figure 2.10), the rail network is very much the opposite. In fact, once the links and nodes have been set down then the rail network is less flexible than the uses to which land on adjacent property can be put (2000, p.466)[15].

[14] This type of issue seems particularly common in the case of HSR, where the accessibility of the nodes is also a factor: "But there is little question that HS2 [the second planned high-speed rail route in Britain] has trimmed the value from property along its proposed route. It has brought the prospect of noise without the promise of a faster way of commuting to London: no station is planned between London and Birmingham" (Clark, 2010).

Figure 2.10: Cancelled Flights in Paris Caused by Ash Cloud from Eyjafjallajökull (Coex and Agence France-Presse, 2010)

[15] Moreover, rail links are by their very nature exclusive, but here, as elsewhere, technology can play a direct role in determining the degree of flexibility in the system: European countries have tended to use flexible but incompatible 'moving block' signals, while British railways relied on a simple but inefficient 'fixed blocking system'. The difference is that when a train is between two signal points on a fixed block network then no other train can enter that segment of line, whereas on a moving block system the exclusion zone moves with the train and varies according to its speed (Railway Technical Web Pages, 2009); this means that moving block systems can be upgraded to carry more trains at higher speeds without reworking the entire system with each increase. This situation is slowly changing, with a European-mandated ECTC moving block system now found on international high-speed lines between France and Germany, and the Brussels to Amsterdam route. Moving blocks are now also found on the Docklands Light Railway (DLR) and Jubilee lines, but their continued absence from the West Coast Main Line will limit speeds for the foreseeable future (Hall, 2010a).

One special case of link flexibility is worth mentioning here: sectional flexibility addresses the fact that differing levels of flexibility may exist within a network: how much latitude is there for adding new links and nodes at various points in the network? We obviously think of telecoms as being particularly flexible in terms of both links and nodes: TeleGeography/ITU (2009) notes that telecoms operators added 9.4Tbps of new international capacity in 2009—more than the total capacity available worldwide in 2007—but while this flexibility is very much true from the end-user perspective, for the owners and operators of submarine cables between continents the case is rather more complicated and some less-developed regions of the world are connected by as little as a single link (Johnson, 2008). Figure 2.11 further illustrates the extent to which capacity is disproportionately distributed on both a geographic and a *per capita* basis around the world, with Europe and North America very densely connected, while Africa subsists on a very sparse set of interconnections.

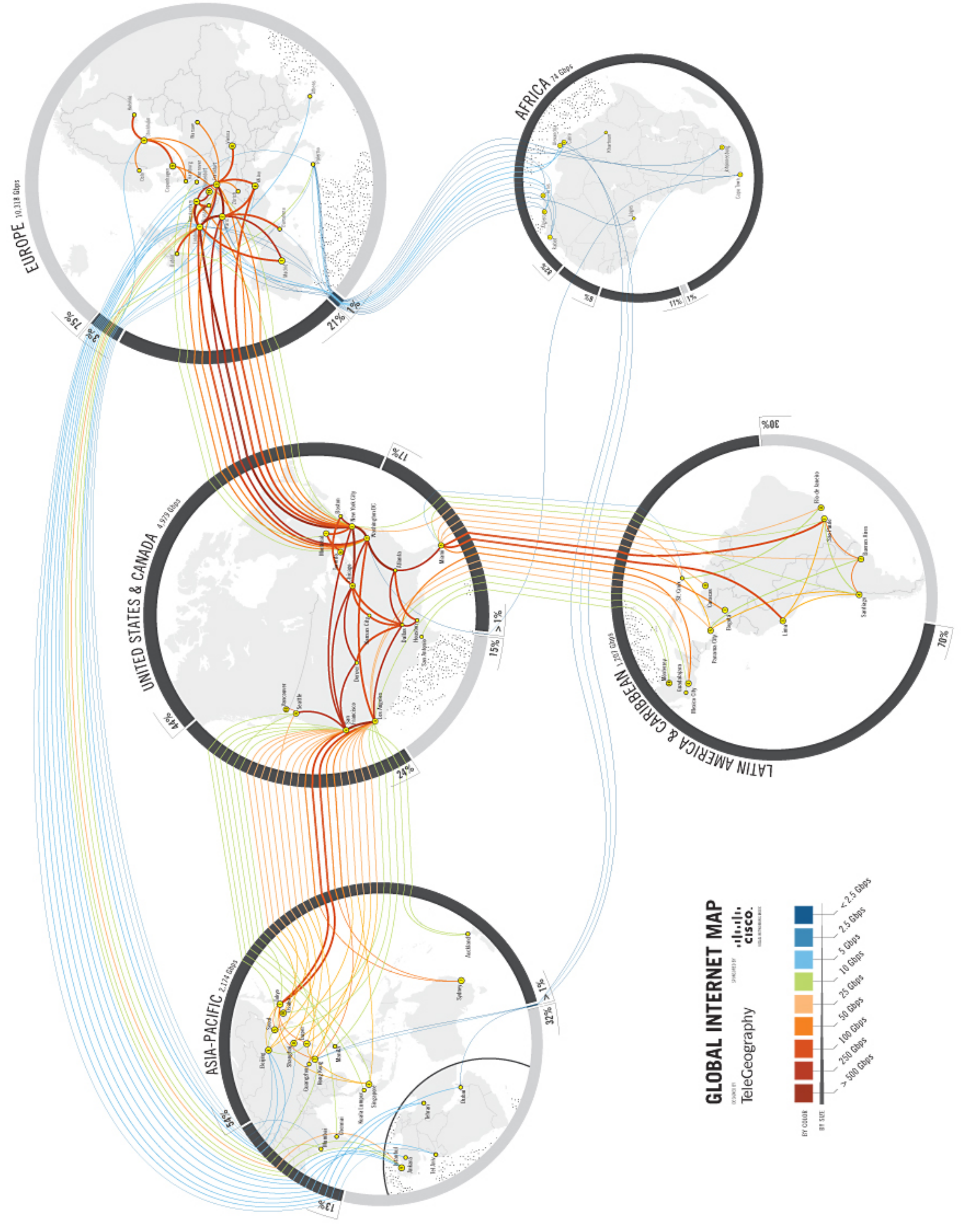


Figure 2.11: Map of Major International Internet Routes (PriMetrica, 2009; reproduced with permission of TeleGeography/PriMetrica)

Temporal Flexibility: The concept of temporal flexibility affects both nodes and links equally, and is concerned with the coordination required to sustain travel across a network as well as the "ability to sequence investments" (Feitelson and Salomon, 2000, p.464). Networks that are highly 'divisible' are ones in which the sequencing of infrastructure upgrades or extensions is flexible, and this means that they too can be more easily adjusted to changes in demand. Often the most flexible networks will be to some extent 'self-organising'—meaning that they lack centralised control—and although less likely to suffer from catastrophic failures of planning or delivery, they are also more likely to suffer from congestion.

For instance, although it is entirely possible for a half-finished highway to be in active use or for interchanges to be added incrementally, it is rather more difficult to put into service a half-finished rail line or airport (Feitelson and Salomon, 2000, p.465). The problems induced by a lack of divisibility can be substantial: the Los Angeles 'Red Line' underground was originally designed to connect the rest of L.A. to the employment hub of its defence sector, but by the time the line was completed the defence industry had largely disappeared (2000, p.470). And although there is clearly a connection between temporal flexibility and the concept of latency—especially in the area of the supply of infrastructure—these two ideas should not be conflated.

In effect, the types of flexibility summarised in Table 2.4 (page 75) relate to the ability of a network to respond to changes in demand or usage. Where this flexibility is limited, such as by the need to manage link externalities, then there will clearly be mismatches between supply and demand and, consequently, periods of underutilisation or congestion (cf. Beckmann, 1978, p.16). Although early underutilisation is often a feature of large-scale infrastructure projects (cf. Flyvbjerg, 2007), a more common problem in the long run is 'overuse', and where this occurs then ICT can be used to manage congestion thresholds upwards, or demand can be constrained using pricing mechanisms. However, in the meantime, "lags in national rollout of services may favour firms in some areas over others…" (Goddard and Gillespie, 1986, p.389)

Upper- and Lower-Tier Networks: As infrastructure networks are more intensively used, their economic costs tend to mount with congestion effects: trains become less comfortable for commuters; deliveries are delayed on busy roads; contention ratios for broadband connections rise, and so on. In other words, costs rise as utility declines, leaving users with a stark set of choices: they can relocate to a less congested area of the network; they can use a less congested network; or they can pay to use comparable networks whose performance is maintained through the manipulation of pricing, access, and capacity (Feitelson and Salomon, 2000, p.475). And while this problem is hardly new—businesses in America's largest cities often paid for priority relaying of their messages on the telegraph system (Tarr, 2004, p.45)—it has certainly become more acute.

In 'upper tier' networks (Feitelson and Salomon, 2000, p.475), the overall reliability, speed, and bandwidth of the network are typically maintained at the expense of its accessibility, cost, or connectivity. Upper tier networks are less generally flexible, and this can be because they carry traffic at higher speeds, because they are subject to greater technical constraints, or because they are designed to address a narrow range of needs. This is as much the case for privately-operated toll highways—which employ complex transponder and camera systems to control access—as it is for business-only airport terminals—whose prices produce a 'kinetic elite' whose "ease of movement distinguishes them from the low-speed, low-mobility majority" (Sheller and Urry, 2006, p.219).

This idea even applies to Internet traffic: although the Internet is capable of routing messages around nodes that are overloaded or unreachable, it also makes no guarantees that packets will be delivered in a timely fashion. So companies with strong telecoms dependencies have switched to using private, parallel networks from companies like Akamai that are able to guarantee service levels around the world or along critical links. Figure 2.12 compares the higher latency and greater packet loss of the public Internet to Akamai's private routes between London and Los Angeles. In both cases less is better, indicating that corporations able to pay for private networks will benefit from superior speeds and integration even if the public Internet becomes congested.

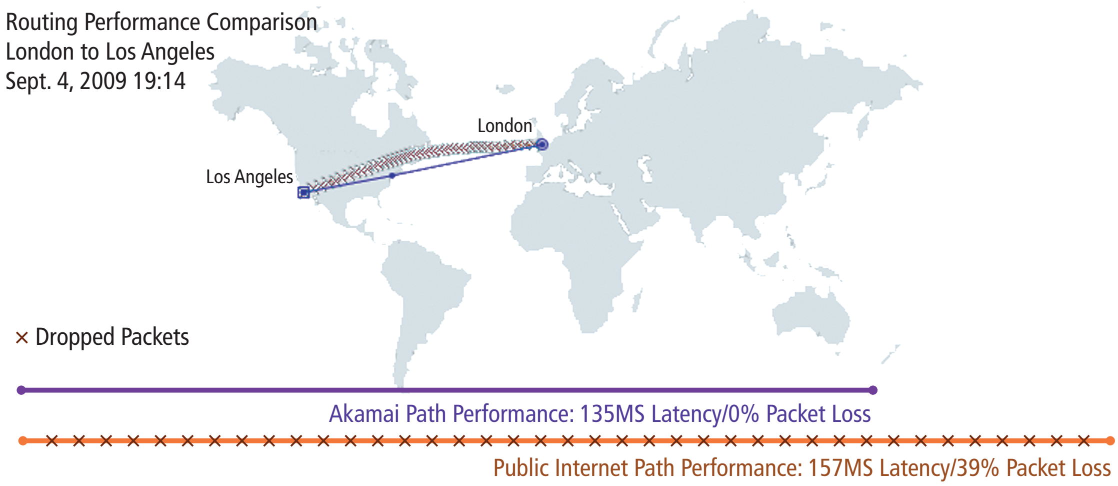


Figure 2.12: Akamai Performance Comparison Against Public Internet (Akamai, 2007; used with permission of Akamai Technologies GmbH)

Design and operation factors for upper tier networks often create greater externalities at nodes and along links (Feitelson and Salomon, 2000, p.475). These constraints, together with the mounting costs of deployment in already-crowded areas, mean that upper tier networks often follow the same link paths as lower tier ones. So high-speed rail routes typically follow rights of way laid out for lower-speed trains, and Eos, Silverjet and MAXJet were set up to operate primarily along the New York-London route where congestion seemed sufficiently high to make their offers attractive. Crucially, this literal path-dependency means that the nodes and links established today are the most likely to be the principal nodes and links of the restricted upper-tier networks of the future as well (2000, p.476). This outcome suggests that it will be much more difficult for today's less-connected nodes to leap to the front of the pack, and that the advantages accruing to the most-connected nodes will be cemented by the upgrade process. It has, for instance, been noted that a good deal of European Internet traffic is still being routed via the U.S. (Gorman and Malecki, 2000, p.116).

Agglomeration & Technology

Agglomeration: We have arrived at the retrospectively obvious, but nonetheless surprising conclusion that a network is constrained by its least flexible element (Feitelson and Salomon, 2000, p.466). So air travel is constrained by airports, and rail by rail links…but how does this work when we depend on several networks simultaneously? Effectively, the answer is a variation on Amdahl's law: in a mix of networks it is the least flexible element of the least flexible network that determines overall system flexibility (cf. Audirac, 2002, p.216). Consequently, the more flexible a network is overall, the *less* it is likely to be factored into individual and organisational decisions.

For instance, homebuyers do not typically consider the availability of landlines in a neighbourhood; instead, they presume that the flexibility of the network will enable one to be added if needed. The same, however, is *not* true for home-workers requiring broadband access since DSL and high-speed cable connections *are* geographically constrained (see Figure 2.13). For firms, especially large firms with dispersed operations and extensive contact needs, the calculation is rather more complex: households may only need to ensure availability, but firms require accessibility across multiple modes and need to juggle this across inputs, outputs, and other interactions.

All of this means that firms will tend to gravitate towards those points in space where they can best meet their mix of needs, and that they will focus on nodes providing access to the relevant geographical scale, be it local, national, or global. So motorways should tend to focus firms with local and regional access requirements around major junctions; but since the number of available interchanges is quite high we would expect that only the most favourably-located (*i. e.* most accessible) nodes will be used. Intuitively, this suggests that from a network perspective highways are implicated in development of edge cities and in the dispersion of business activity since their layout permits (relatively) quick and convenient access for labour at the risk of greater inconvenience for meeting with other firms. We will return to this idea in Chapter 4.

Meanwhile, the airport's attraction is likely to be to businesses operating on a national or international scale, and so the rise of what Kasarda (2000b) terms the 'aerotropolis' reflects the dependencies of global businesses. The development of business activity at the airport is astounding: Schiphol now employs as many people (approximately

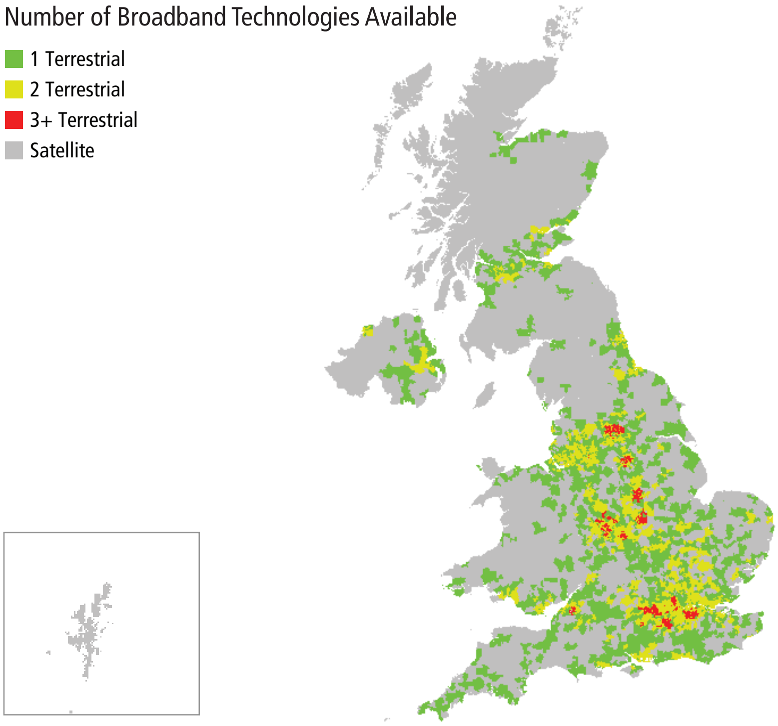


Figure 2.13: Map of British Broadband Availability (Department of Trade and Industry, 2004; reproduced under Crown Copyright)

50,000) as Amsterdam's traditional Central Business District (CBD) area (Bertolini, 2005, p.68). Interestingly, development of the Zuidas (South Axis)—which is Amsterdam's answer to London's Docklands—was first pencilled in for the area to the West of the Dam, but developers attempting to "attract foreign firms specialising in financial, legal, and business services" insisted on an area with better access to Schipol (Bruinsma, 2009, p.110). In turn, developmental constraints at Zuidas led to its being rejected by some firms in favour of Amstelveen, which is also close to the airport but has fewer space constraints (*ibid*). This pattern "points to selectivity about times and places of interactions" (Bertolini, 2005, p.72), and helps to explain why new business centres in Amsterdam have typically sought to combine superior public and private transport access (2005, p.68).

Feitelson and Salomon go so far as to argue that the main stages of urban development are intimately connected to technological change in the transport sector and its supporting infrastructure (2000, p.460). And clearly, changes in the relative flexibility of a mode or modes can have dramatic economic impacts: containerisation allows many different products to be handled with just one type of standard hardware, enabling boats to be loaded and unloaded much more quickly and for goods to be routed to their final destination without warehousing. So at the larger scale, the decline of the 19th and 20th Century's port cities (including London and New York) and the shift towards deep water ports such as Rotterdam can be directly connected to the increased flexibility of the shipping and trucking networks. But even as it has increased the speed of delivery, the use of palettes has made other segments of the network *less* flexible: Tesco finds it easier to fulfil on-line customer orders from local shops than to use a centralised system that would require palettes to be broken up before delivery to the shop (Murphy, 2004).

Technology: In contrast to this, telecoms infrastructure should theoretically have little impact on urban development because *most* firms can meet *most* of their telecoms needs from almost anywhere. As an extension of the office park, the short-lived concept of the 'teleport'—a site of privileged access to telecommunications networks—must have been largely obsolete before the first one was even built. Graham (1997, p.109) mentions one U.K.-based teleport that placed a large, but entirely extraneous, satellite dish outside to suggest its otherwise invisible functions (see also Graham and Marvin, 1996, p.51). However, there is a tension here between the ubiquity of advanced telecommunications in the heavily interconnected core urban areas—where its ubiquity actually works against its being a factor in the majority of decisions (Feitelson and Salomon, 2000, p.472)—and its general absence in the rural regions of developed countries and across large swathes of less-developed countries.

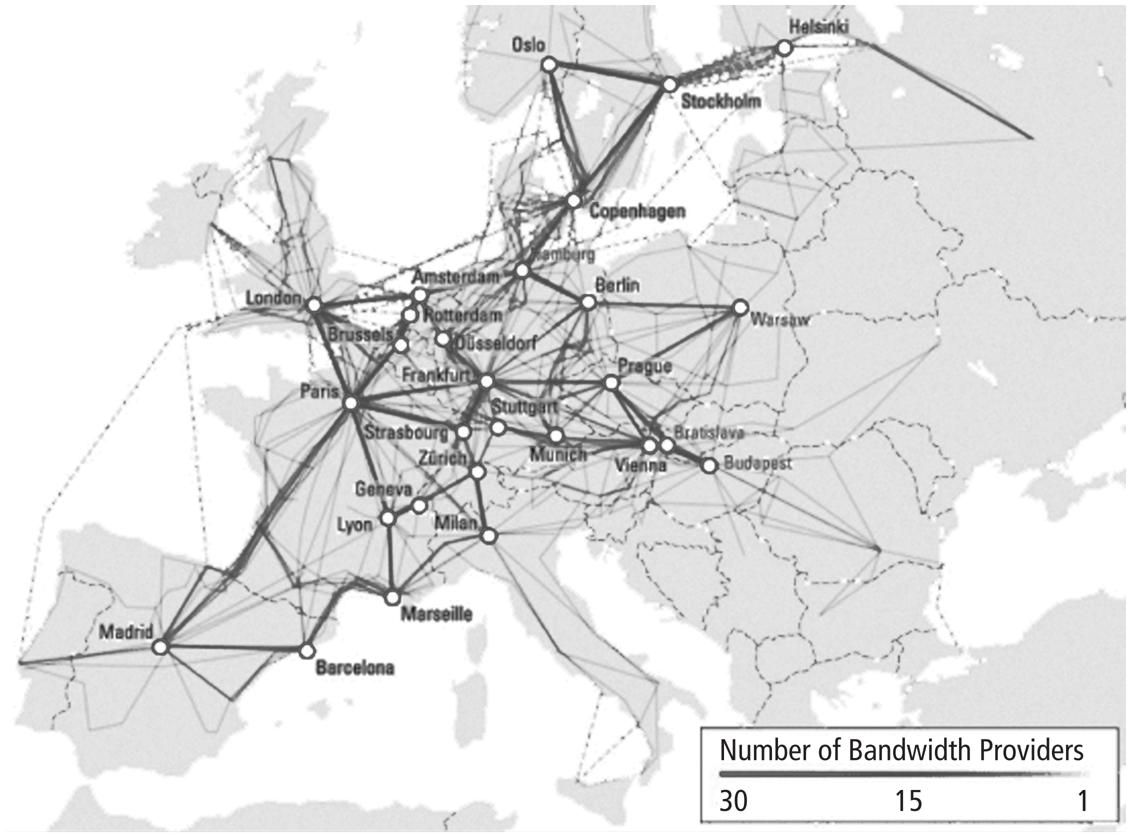


Figure 2.14: Map of European Connectivity (PriMetrica, 2004; reproduced with permission of TeleGeography/PriMetrica)

So at the margins, the distribution of telecommunications infrastructure is still very definitely not uniform; for example, much of the geography shown in Figures 2.13 and 2.14 can be attributed to demand concentration and to the ability to pay of households and businesses. Figure 2.14 also shows the extent to which inter-urban bandwidth provision is skewed towards the largest cities of Europe, with London, Paris, Amsterdam, and Frankfurt particularly well-represented. This distribution clearly shadows the historical 'Pentagon' of business activity (Pain and Hall, 2008, p.1068; Hall and Pain, 2006, p.4[16]), though there are also some surprisingly high levels of integration with more peripheral areas.

[16] I note, however, that the text and figure in the POLYNET study appear to contradict each other in terms of the vertices of the pentagon falling in Holland and Germany

Zook (2004, p.203) showed that, together, Los Angeles, New York and San Francisco had more domain names in 2004 than the next 12 largest metro regions combined, but Townsend found that there had been a shift in the *density* of new domain registrations towards "university towns and corporate R&D clusters..." (2001, p.43) Putting these trends together, it seems that the combination of demand and income factors tilts provision towards the parts of the country that are both densely-developed *and* wealthy: Traxler and Luger (2000, p.293) found that San Francisco, Silicon Valley, Washington D.C., Chicago, New York, Dallas, Los Angeles, and Atlanta accounted for 62% of U.S. backbone capacity. So the economics of infrastructure provision tend to reinforce the path dependency of major infrastructure (especially upper tier infrastructure), and this is one reason to agree with Goddard and Gillespie's assessment that "new transmission systems will favour existing concentrations of economic activity" (1986, p.388). Only the recent emergence of Dubai as a global air hub suggests that a fortunate geographic location, great wealth, favourable regulation, and an enormous, sustained investment in infrastructure creates some capacity to overcome existing network lock-in.

Spatial Implications

So we have a spectrum of flexibility: at the one end are the networks such as telecoms and roads that are capable of offering nearly ubiquitous service across space, while at the other end are the restricted 'nodal networks' that bind development to key locations. The former class of network tends to equalise space by making all areas equally accessible, while the latter accentuates the difference between connected and unconnected regions. We can therefore concur with Bertolini's suggestion that "connectivity is analogous to the 'space of flows'" (2005, p.73) and that it is simultaneously "what enables the spatially [and temporally] disjointed city to keep functioning" (*ibid*), and what lies at the root of a rise in global inequality between haves and have nots (Castells, 1996 [2000], 2000).

As I have argued above, we can think about the spatial effects of increasing mobility in terms of accessibility. However, as Bertolini and Dijst (2003, pp.27–28) very rightly point out: accessibility relies on "...the quality of the connections to transportation and communication networks at multiple spatial scales...[and that] accessibility [also] combines with other, more proximate features of a location to determine sets of conditions—a 'mobility environment'". Knoben and Oerlemans (2008, p.387) do not use the term, but they are clearly addressing the same mix of factors when they find that firm relocation is affected by the "distance to infrastructure facilities and type of area in which firm is located…" More concretely, Breheny (1999, p.179) points to a 'Heathrow economy' that is premised on the existence of firms for which "proximity to air infrastructure is significantly positive" (*ibid.*).

However, Bertolini and Dijst (2003, p.38) are also careful to note that we should be wary of assuming that 'a simple one-size-fits-all prescription' would do for all industries. So even if the airport is a "place where people and objects are transmitted into global relationships" (Sheller and Urry, 2006, p.219), it will still pay to think about which firms require this type of mobility as part of their day-to-day operations, and which ones do not. The mobility environment does away with hierarchical relationships, physical spaces, and fixed infrastructures, allowing us to think more flexibly about how different mixes of access and attraction emerge (or might be encouraged to arise) in a variety of contexts, but we will need to examine how this interacts with the requirements of individual firms and sectors in order to more fully grasp its implications for the city and city-region.

Summary

What we have seen in this section is that they key to understanding locational behaviour is the degree of flexibility that firms and households have with respect to the infrastructure upon which they rely (see Table 2.4). The process of choosing where to locate involves trading off various networks against one another, as well as against the more basic requirements of rents, labour, and plant, creating what we might term a 'relational geography'. The second key point is that in contemporary infrastructure 'proximity no longer implies any particular relationship' (Graham, 1997, p.120), and that this holds not only for telecommunications, but for *all* types of infrastructure. This disjoint, relational space is much more complex than the 'flat plain', but ultimately offers a better way of understanding and responding to the needs of businesses and households.

We can also consider these issues in terms of transport costs as a share of the total cost of high-value goods. What is interesting about contemporary transport and communications infrastructure is that shipment costs are no longer so much a function of distance as they are of time (*i.e.* speed and latency). There is an increasingly non-linear, non-Euclidean dimension to inter-firm competition: air travel, HSR, and telecommunications permit, and may actually enforce, non-hierarchical, spatially-disjointed development, making a focus on interlocking 'market areas' unhelpful. Increasingly complex geographic arrangements are evolving (Gillespie and Robins, 1989, p.113), and we are dealing not with the hierarchy foreseen by Christaller, but a network of complementary nodes in shifting relationships to one another.

We cannot, for instance, understand the global shipping network solely in terms of its ports, we must also consider the road and rail net-

Dimension	Motorized Transport		Rail Transport			Air Transport		Telecoms	
	Roads	Highways	Metro	Suburban and Inter-city	High-speed	International	Domestic/Regional	Fixed-Line Telecoms	Mobile Telecoms
Node size	○	●	◒	●	●	●●	●	○○	○○
Node requirements	○○	●	○	◒	◒	●●	◒	○○	○○
Node externalities	○	◒	○	◒	◒	●●	●	○○	○
Link requirements	○○	◒	◒	◒	◒	●●	●●	○	○○
Link standards	○	◒	◒	●	●●	◒	○○	○○	○○
Link externalities	○	◒	◒	●	●●	●	◒	○○	○
Traffic externalities	◒	●	○	◒	◒	●	◒	○○	○
Complementary infrastructure	○○	◒	○	◒	◒	●●	●	○○	○○
Divisibility of investment	●●	◒	◒	○○	○○	○	○	●	●●
Need for central control	○○	○	●●	●●	●●	●●	◒	○	○○

○○ = Minimal ○ = Minor ◒ = Modest ● = Significant ●● = Major

Table 2.4: Network flexibility dimensions (after Feitelson and Salomon, 2000, p.467)

works to which each port is connected and the markets to which those give access (Fowler, 2006, p.1445). And in this example we should not forget that shipping firms "have the flexibility to carry cargo through a range of ports…[and] can use this power to force ports to compete in offering lower rates, higher productivity, improved infrastructure, etc" (2006, p.1443). We will therefore need to move beyond the somewhat passive/responsive notion of firms advanced in Chapter 2 towards a more active model in which they are 'actors within networks' able to shape patterns of flows and "develop profit-maximising strategies outside of the interests of the cities" (2006, p.1430).

The flexibility issue means that the specific geography of networks, even the digital ones, affects the differentiation of space (see Table 2.5). The world is increasingly divided into those places that are connected and those that are not: "often [advanced telecoms and transport infrastructures] link nodes and city centres together into networks while excluding much of the intervening spaces from accessing the networks, because the networks pass through these spaces without allowing local access" (Graham and Marvin, 1996, p.60). Consequently, we have no reason to expect that the emergence of upper tier networks and our increasing reliance upon them will herald the 'liberation' from space envisioned in the late 20th Century (Feitelson and Salomon, 2000, p.476).

This dependency helps to explain the 'paradox' observed by (Hall, 2003, p.142): that the deployment of the telephone seems to have con-

Network	Access points	Land use effect
Roads	Free access	Dispersion of development
Motorways	Interchanges	Development around interchanges and beltways
Rail	Rail stations	Development around stations
Metro	Metro stations	Development around CBD
Air Transport	Airports	Business concentration around major airports
Shipping	Ports	Industrial development around ports
Tele-communications	Computers, Phones	(Possible) Dispersion of business locally

Table 2.5: Land use effects of selected networks (Feitelson and Salomon, 2000, p.469)

centrated, rather than dispersed, business activity. In effect, as congestion rises across a broad range of networks, we are increasingly bound to those restricted locations—the global megacities and megacity regions—where the upper tier networks are accessible. This multi-modal flexibility issue lies at the heart of Traxler and Luger's observation that "economic functions become footloose only in areas with advanced telecoms infrastructure, skilled labour, and good airport access" (2000, p.289). Agglomerations are therefore most likely to develop around the nodes of the least flexible networks (Feitelson and Salomon, 2000, p.476), and the degree of development will be greatest where the network dependency of firms is highest.

Of course, the least flexible nodes are those of the upper tier networks, and it is in this light that we should understand the vast sums of money spent redeveloping the Kings Cross area of London in preparation for the arrival of the Eurostar, or in developing EuraLille, which from a regional development standpoint is not a great deal more than a place where two major high-speed rail lines meet. To put it bluntly: "Global markets in capital, product and labour tend to be more accessible via cities and large urban areas. Advanced producer service (APS) firms increasingly use major cities as hubs for global business networks. Similarly, big cities are sites of international migration—often highly-skilled people with new ideas and links to markets 'back home'" (Athey et al., 2007, p.21).

2.5 Conclusions: Telecommunications & Regional Economics

As our review of Christaller and Lösch should have made clear, access to high-quality infrastructure enables firms to engage with markets at multiple scales. For businesses, the right mix and availability of transport and communications infrastructure is essential, and NESTA reports that: "All the sectors studied served global as well as local markets, with global markets tending to take priority. International connectivity is therefore important. Transport infrastructure was cited as a major asset for facilitating business connections, networks and knowledge transfer" (2007, pp.28–29). What the addition of flexibility and performance characteristics enables us to begin to understand is *how* some sites become privileged at the expense of others, why these inequalities are so difficult to rectify once they have taken hold, and why the "functional hierarchies of cities within nation states that were described so painstakingly within central place theory are breaking down" (Graham and Marvin, 1996, p.58).

However, Christaller's emphasis on the function of places—not on their physical or population sizes—helps us to understand how some nodes, especially those where multiple networks intersect, become optimal locations for development because "firms are opting for places that are optimal in terms of connectivity rather than proximity" (Audirac, 2002, p.221). And cities remain the place where this occurs with the greatest frequency, intensity, and density, so "the role of cities as transport hubs with key road, rail and air links can also be a significant benefit to businesses since this gives them good access to customer, suppliers and collaborators located elsewhere within the city-region. As the global economy becomes more integrated, international transport connections are becoming particularly important" (Athey et al., 2007, p.17). And the concept of upper-tier infrastructure helps us to understand why technological change is currently reinforcing uneven regional and national development, superimposing new types of spatial exclusion on top of existing ones (Gillespie and Robins, 1989, p.15).

So we may now propose that 'centrality' is not a product of the diversity of consumer goods, but of the number and type of networks intersecting in space. Global firms should show a preference for access to global networks, while local and regional ones should show a greater diversity of locational strategies, reflecting the greater range and variety of locally complementary and competing networks. For example, a segment in BBC Four's *The Secret Life of the Airport* examines multinationals based at Stockley Park and finds that its principal draw is that it is just a few minutes from Heathrow and so highly accessible for executives and clients arriving from abroad. We can predict that hubs with many infrastructure connections will tend to outcompete less connected ones for the offices of large, sophisticated firms, undermining the smaller sites' capacity for innovation: "Weak urban hubs often mean that innovation specialisms of sectors are much narrower than in other cities that function as stronger hubs" (Athey et al., 2007, p.4).

In a review of the implications for the city of 'contemporary communications', Hall (2003, p.150) argues that the emergence of the superstore and of national chains demonstrates "the dramatic increase in mobility and thus in what [Christaller] termed the 'range of a good' in the 70 years since he wrote…" This is an important point, but I believe that the discussion of consumer-goods is telling: at its heart, Christaller's model is one where "retail gravitation is the main force [and] this is shaped by customer convenience…and willingness to travel…" (Vance, 1970, pp.140–141). Combining this with a network-oriented analysis, it now makes sense why an exclusive clinic 'offering everything from orthopaedics to plastic surgery' would chose to locate itself in a major airport (Economist Intelligence Unit, 2006, p.53).

However, a retail-gravitation approach is of comparatively little help for exploring business-to-business services, and of the locational factors affecting such non-consumer oriented sectors such as wholesale finance, merchant banking, R&D, or consultancy. Moreover, so far we have thought about the firm in an abstract sense, and have not considered the network affinities of businesses in any kind of systematic way: which firms? which sectors? and why? Unpacking the idea of the firm is essential to developing a better understanding of its effects on infrastructure, cities and regions. Chapter 3 will therefore seek to develop an understanding of the ways that industrial activity is changing in the 21st century and what these shifts portend for the locational preferences of firms. What we *can* say here is that the tiered aspect of these multiple infrastructures highlights one reason why innovative firms, and especially advanced producer services (APSs), may be even more place-bound than their less sophisticated brethren: they are increasingly reliant upon upper tier networks for the efficient movement of people and information on a global scale.

There have been suggestions that the emerging, networked city "operates in an economy where the transport costs of the highest value products (information and knowledge) are fairly insensitive to distance" (Townsend, 2001, p.56). Drawing on the concept of network flexibility, this chapter has attempted to lay the groundwork for an argument, which will be developed in greater detail over the course of the next three chapters, that this is not in fact the case. And it is important not to overlook the fact that network development is mediated by policy and politics: "…policy areas such as transport influence innovation by shaping market access" (Athey et al., 2007, p.6). We can therefore think of flexibility as both an attribute of infrastructure networks, and as a deliberate objective of regional and national policy: so increasing the number of locations where infrastructure overlaps may increase the number of choices available to firms, whereas restricting this overlap may help to focus economic development on carefully-selected 'key sites' and also decrease the overall cost of the deployment. Depending on the situation either approach may have merit, and so this requires us to make active choices about where and when to invest for the future.

3
Firms, Markets and Risk

3.1 Introduction

In the preceding chapter we set out models of regional development that were heavily influenced by transport costs, to which we added both an understanding of telecommunications networks and of the constraints of infrastructure flexibility. However, beyond some basic predictions this high-level view did not make clear why some firms and sectors would be dependent on some transport and telecommunications modes, but not on others. Or as Haig (1926b, p.422) asked rather more directly: why have services firms remained concentrated in the central business district (CBD) when bulky goods—which are much more costly to move around—have not? And, we might add, why has this pattern persisted into the 21st Century?

In a nutshell, understanding the origins of these dependencies and their expression in space is the purpose of this chapter. To accomplish this, we need to examine how space affects the structure of the firm, as much through transportation and communications as through factors that only become relevant at this finer scale. We need to consider why a firm should choose one location over any other possible location (Weber, 1909 [1969], p.xxii), and to do so we need to examine not only the nature of the firm, but also the nature of the markets in which it operates (cf. Coase, 1937). We will see that although the firm is in part a vehicle for the spatial division of labour (which has been well-studied), it is *also* a means of managing risk and information (which has been less so).

The challenge is that the firm itself is becoming more complex and flexible thanks to the "easing of locational restrictions, [and] extension of work and company boundaries" (Panteli and Dibben, 2001, p.383). So a major step in this analysis is the deemphasis of the firm as an atomic entity and a focus on how informational and transactional flows between units help to define the firm. We then look at how those flows are also connected to the firm's interactions with competitors and collaborators (cf. Scott, 1983a), and the organisational pressures that result (cf. Robinson, 1931 [1943]; Marshall, 1890 [1948]).

Firms

It turns out that surprisingly little was written about the factors driving individual firm location during the period between the original works of Weber (1909 [1969]) and the other thinkers of the early 20th Century, and their 'rediscovery' in the 1970s and 1980s (Bellet and L'Harmet, 1998, pp.ix-x). This long pause obviously coincides with the period between the ending of the 2nd Industrial Revolution and the onset of globalisation in the 1960s, but it still means that thinking on industrial location has given comparatively little attention to services, and still less, with the notable exception of Goddard (1973), to information.

So although we should not overlook the ongoing importance of the trade in physical products to the global economy, the lack of a proper emphasis on services seems an important gap in our understanding of contemporary firm location strategies. Returning to Weber's original model enables us to begin with a fairly simply model of firm locational factors, to which we will add detail and complexity over the course of this chapter. And while we are, like Weber, also attempting to build a generic model of firm location, we cannot do so without taking into account—in a limited way, for now—the sector in which the firm operates and, in particular, its informational characteristics.

Markets

In Chapter 2, I began to argue that the traditional assumption of a flat plain is, at best, a profoundly misleading metaphor in a network context: it causes us to imagine a 'frictional effect of distance' such that 'larger distances discourage interaction' (Graham and Marvin, 1996, p.55). Critically, early location theory largely overlooks the fact that not only does space affect the cost of goods and services, but it also affects our ability to determine what they should cost in the first place. Graham and Marvin (1996, p.56) put it this way: "one of the key simplifying assumptions…[is] that producers and consumers had perfect information about the choices open to them: the services they could consume and how, the changing nature of markets and organisations and legal, technological and regulatory developments."

So if space affects our ability to make informed decisions about the value of products or services at remote locations then there may be little reason to assume that information is distributed symmetrically in most, or indeed any, markets. As a result, we lose a great deal of certainty about many core aspects of doing business and this introduces the essential concept of spatially-determinate risk. We will see that this begins to explain why some sectors cluster together in space in spite of the apparent advantages available to a firm that moves to a more distant, lower-cost location. In short, it is about managing risk and information, and these two factors are becoming increasingly important as markets become ever-more global in scope and interconnected in nature.

Transactions

If the market creates the 'playing field' upon which firms operate, then it is the unique pattern of transactions and interactions of each firm that structures its particular spatial strategies. Defining transactions according to dimensions such as as volume, stability, and intensity, enables us to make predictions about the likely dependencies of firms in terms of their proximity requirements to suppliers or customers, and their ability to manage growth internally or through externalisation. We will see that firms in a range of fields pursue complex and sophisticated strategies to mitigate the cost of a transactional failure.

The study of transactional and informational flows will also emphasise the fact that while the historic requirement for literal proximity may be weakening, the ongoing need for accessibility is not. A critical component in this process has been the revolution in our ability to exchange data electronically, which has extended the firm's ability to coordinate activity across long distances effectively. In some cases, this seems to lead to new levels of centralisation, but far more often it seems to permit firms to hive off 'extraneous' functions (everything from marketing to production) and to focus themselves on a core endeavour. And this implies that we will need to be careful, as Goddard (1973, p.54) suggested, 'in distinguishing between geographic dispersal and functional decentralisation.'

3.2 Theory of Firms & Locations

Early thinking on firm location was profoundly influenced by the impact of the Industrial Revolution, and this is reflected in the interest of Alfred Weber (1909 [1969]) in how raw materials are extracted, transformed, and shipped to final markets in a multitude of forms. Unsurprisingly, an industrial firm's locational decisions are principally structured by the cost of moving raw and finished materials across space. However, the shift towards a services-driven economy over the course of the 20th Century means that we will now need to give particular attention to firms whose only inputs and outputs are raw or processed information; these firms are clearly far removed from Weber's coal and timber users, and so would appear to suggest some major challenges ahead.

Simplifying Assumptions

In addition to the flat plain, Weber makes four simplifying assumptions that are particularly relevant to our study[1]: that labour is not mobile (1909 [1969], pp.38); that the transportation system supporting this economic activity is uniform (1909 [1969], p.42); that the movement of inputs or outputs is charged on a per-mile basis (1909 [1969], p.43); and that the geographical configuration and scale of demand are constant within the market area of the firm (1909 [1969], p.38). This last assumption was strongly criticised by Lösch in *The Economics of Location* (1954 [1973], p.261), but holding all of these potential factors constant

[1] The other assumptions that Weber makes are important for setting the limits of the model, but are not particularly relevant to our analysis in this chapter: that the geographical distribution of input materials is fixed; and that the geographical distribution of final markets is also fixed (Weber, 1909 [1969], pp.37–39).

freed Weber to focus on transportation costs as a form of 'friction' affecting the production and distribution of goods. We will now consider each of these assumptions in more detail.

LABOUR MOBILITY: Assuming that labour is immobile significantly simplifies Weber's model by making human capital very much like any other natural resource for the purposes of his analysis. And while people—young people especially—*do* seem to relocate in large numbers in the pursuit of learning and employment, capacity constraints can impose limits on migration even where opportunities abound. So labour supply constraints are thought to explain why we typically find higher wages in major cities such as London (Shaw and Jefferies, 2005, p.38). Clearly, the makeup of the housing market, and especially the proportion of owners to renters, will also impact the inclination of labour to respond to new opportunities at remote locations (cf. Surowiecki, 2008).

However, the shift to a services economy, especially as buttressed by the deployment of Information and Communications Technology (ICT) systems, seemingly renders this whole issue a moot point. For instance, in the 1990s Ireland pursued a strategy aimed at bringing skilled but spatially-flexible jobs in financial services, publishing, and software development to its English-speaking workforce (Graham and Marvin, 1996, pp.148–149). The early success of these efforts suggested that, outside of the personal services sector, the relative mobility of services allows business to bring on additional workers by electronic means. And certainly, the success of international call centres and of remote collaboration amongst teams within multinationals in the technology sector suggest that this *is* happening on a substantial scale.

And yet, during the 1990s almost one-third of inter-regional relocations and nearly one-fifth of intra-regional moves within the U.K. were job-related (Shaw and Jefferies, 2005, p.25). And labour is increasingly mobile at the international scale as well: "[o]ver half of Silicon Valley's scientists and engineers were born abroad, mostly in South and East Asia…and help attract a constant inflow of skilled people" (Athey et al., 2007, p.21). These migrations are obviously being driven by employer demand but the underlying fact is that, at the higher-paid end, this labour is clearly not interchangeable (Charlot and Duranton, 2004, p.5). The volume of relocation and the scale of costs incurred by employers suggest that even if labour is much more mobile than Weber had anticipated, there is nonetheless a spatial aspect to skilled services delivery that merits further investigation.

TRANSPORT UNIFORMITY: The equivalence of transport modes that Weber assumes is initially difficult to comprehend (1909 [1969], p.43), since choosing between land, sea or air freight so clearly has dramatic implications for the delivery of goods. However, as we established in Chapter 2, the economic cost of travel is really a measure of utility that incorporates non-monetary factors such as reliability, speed, latency, and frequency of service. Because the unit of analysis is the same, then all modes of travel are functionally equivalent for analytical purposes. This crucial 'sleight of hand' enables Weber to show that, for his purposes, waterways and railroads are part of the same network: "for within such a system, routes with cheaper rates mean nothing but distances shortened in proportion to the decrease in rates" (1909 [1969], p.84).

Conversely, competition between firms on the *same* routes is addressed by treating each company as though it operated on a separate network with its own cost structure (Weber, 1909 [1969], p.80). The emergence of private competitors to the national postal system illustrates the relevance of this treatment: the Royal Mail, FedEx, and UPS operate parallel delivery networks that use separate vehicles, processing centres, and transhipment points, but all deliver to the same sets of addresses. The varying monetary costs of each network are simply a reflection of the way that each firm has selected for different characteristics such as reliability or speed.

Ton-Mile Shipping Costs: The unit of analysis in Weber's model is the 'ton-mile', and it enables him to address a surprisingly broad range of transportation issues that we might initially think are exogenous to his theory. The key, as already implied by his handling of competing modes and distribution networks, is that we can modify the weight moved and distance travelled to reflect attributes such as speed, convenience, or congestion (1909 [1969], p.43). So bulky goods can be represented as an extra weight to be transported, poor-quality infrastructure can be treated as extra miles to travel, and when dealing with economies of scale: "...distance can be thought of as varying according to the percentage of the decrease whenever such scales apply" (1909 [1969], p.44). Even input substitution can be incorporated through a tinkering with the locational weight of inputs and the overall 'pull' that they exert on the optimal point of production.

The shipping costs of a firm's inputs and outputs lead it to locate at the point where the total ton-mileage of inputs and outputs is at a minimum (1909 [1969], p.48). If the final output is 'heavier' than its inputs, then the firm will tend to move nearer to its customers; but if the inputs, either individually or collectively, weigh more than the output then the tendency will be to locate nearer to either the most costly resource consumed, or to some weighted average of all inputs (1909 [1969], pp.59–60). Figure 3.1 illustrates two simple production processes involving two inputs and one output of varying weights[2]. In a dynamic context, if the cost of movement changes, then the relationships between inputs and outputs, and the optimal location for the firm can also change.

[2] In some cases a resource such as coal is consumed during the production process, in which case we also have to grapple with 'weight losing' materials which add nothing to a product's final locational weight but must still be shipped to the point of production; these will also tend to draw production towards the inputs and away from the final market (Weber, 1909 [1969], pp.63–64)

Kasarda (2000a) suggests that the emergence of the 'aerotropolis' is being driven by the need for global movement of goods and people, and by the decline in the perceived quality of urban infrastructure. Similarly, there is ample evidence to suggest that growth at well-connected sites such as Amsterdam's Zuidas is supported by its relative accessibility, not only for Dutch workers from both urban and suburban areas, but also for international arrivals from Schiphol Airport and from the

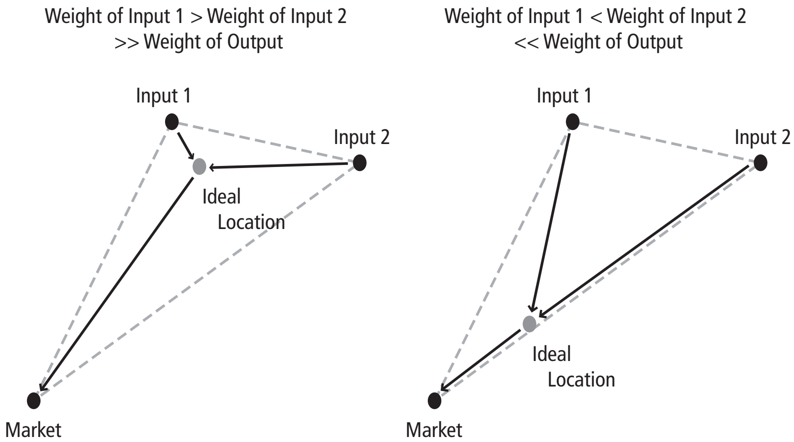


Figure 3.1: Illustration of Inputs Affecting Plant Location

new high-speed rail line running to Belgium (cf. de Graaff et al., 2007, pp.2099–2101). This is much the same argument that was later advanced by Christaller (1933 [1966]) and Lösch (1954 [1973]), but it spatialises the internal operations of the individual firm in a way that neither of the other authors does.

Locational Factors

Having established these underlying assumptions, Weber's model explains firm spatial preference with five factors: labour, materials, transport, perishability, and dependency. Weber argues that three 'general factors' of labour, materials, and transport can be applied to all firms, with transportation costs providing an overarching framework, while the two special factors of perishability and dependency apply only to some firms (Weber, 1909 [1969], pp.20–22). Our primary interest here is the extent to which these factors successfully account for the location patterns of contemporary firms, and especially those that use information as both an input to, and an output of, their operations.

General Factors: The relationship between labour and the firm can be nicely captured by Weber's 'labour index' (1909 [1969], pp.107–108), which is a measure of the value added by workers to the production process. Bellet and L'Harmet (1998, p.129) term this the 'coefficient of labour' and define it as the total labour input per unit weight of product. In a contemporary context we might think of this as the information-processing capacity of workers, so for specially-trained workers such as scientists, software developers, artists, and designers, we would expect a higher labour index than for employees in less-skilled fields such as personal services, call centres, and manufacturing.

As we saw above on page 83, firms will generally try to keep the distance over which inputs and outputs are transported to a minimum, since they incur costs for each kilometre something is moved. However, in certain circumstances, the distribution of skilled workers might make it necessary to ship materials over long distances in order to take advantage of a localised labour asset, as illustrated in Figure 3.2. At the limit, such as in creative endeavours like fashion design where the value of a name-brand designer is nearly limitless and the output (*e.g.* a design) quite easy to transport, the decisions of Lösch's "gifted men who refuse to migrate" (1954 [1973], p.23) may mean that some firms follow workers rather than the other way around.

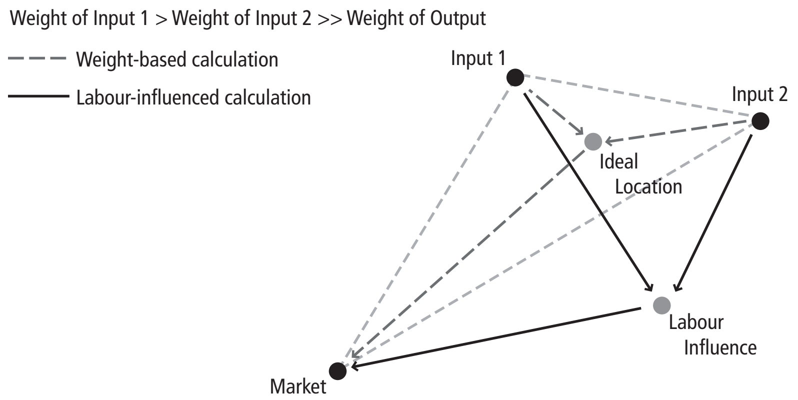


Figure 3.2: Illustration of Labour Index Affecting Plant Location

Florida (2002a) makes much the same argument, though minus the Weberian terminology, in *The Rise of the Creative Class*. One of the essential claims of Florida's work is that the growth industries of the 21st Century must adjust to the locational preferences of labour (see also Gaschet, 2002, p.65), and that this creative group increasingly prefers diverse, tolerant cities to monocultural suburbs, producing the capacity for fine-scale divisions of labour in all fields, including the cultural (cf. Scott, 2001). In principle, for some industries only the location of labour matters, in which case the labour index will tend towards infinity.

However, it is not just in creative industries that this requirement arises: it is hardly coincidental that the off-shoring of support centres and software development has tended to favour English-speaking India over China, which has a comparable—or even superior—infrastructure. In the case of engineering and technical support, telecoms-based interactions are usually easier (and often cheaper) when the participants share a basic linguistic 'proximity' (cf. Skinner, 2004; Graham and Marvin, 1996). However, graduates of Indian engineering schools can still find themselves needing to attend 'finishing schools' where they learn the 'soft skills' of etiquette and communication skills in order to improve their employability (Pandey, 2010; Blakely, 2008). And this is actually becoming a two-way street, with growing demand, especially in North America, for cross-cultural training courses for all staff (Mohn, 2010).

Although the data comes from 1996, Table 3.1 highlights the extent to which the traditional location factors—labour and transport—still play a vital role in locational decisions. The highest-rated factors are all accessibility-related: the rail network and major airports. Next comes the availability of labour, with the relative importance of white and blue collar workers varying with the nature of the work to be done. Interestingly, in the case of white collar labour *cost* tends to count for

Table 3.1: Importance of Location Factors by Establishment Function (from Gordon 1996 in Breheny, 1999, p.181)

% of Respondents citing factor as important	Administration	Distribution	Manufacturing	R&D	Sales/Marketing	Services	Total
Cost of labour	27	15	14	14	9	13	13
Availability of white collar labour	33	35	21	26	39	22	29
Availability of manual labour	7	25	39	14	3	7	14
Availability of general business services	0	5	0	3	0	5	2
Availability of specialised business services	0	5	0	4	3	5	4
Availability of premises	0	10	21	15	9	16	14
Cost of premises	20	25	29	32	33	35	31
Proximity of customers	7	25	18	28	30	36	28
Proximity of suppliers	7	20	18	7	9	4	9
Proximity of competitors	7	10	0	8	6	15	7
Availability of adequate housing	7	5	0	3	6	5	5
Traffic congestion	13	15	11	10	6	11	9
Access to London	27	25	11	22	24	33	26
Good rail connections	33	25	21	22	15	36	26
Access to national rail network	40	60	50	56	48	51	54
Access to major airport	40	30	25	22	33	22	28
Number of Cases	15	20	28	18	33	55	163

less than availability; this might seem obvious, but it is not always clear that policy-makers grasp this basic constraint. The cost of premises are also important, but are often ranked below that of labour. Finally, although we will not explore this issue here, I wish to also point out that firms in some sectors also rate the proximity of suppliers, competitors and customers quite highly as well.

Special Factors: For obvious reasons, Weber's general theory of industrial location largely glosses over the special factors affecting firm location (1909 [1969], p.20), but the absence of detail around the concepts of perishability and production dependencies seems like another important gap in this developing model. Many products in use today are perishable *and* shipped over surprisingly long distances. So, can Weber's model still serve to explain the movements of goods and services through global supply chains using only the concept of the ton-mile?

One way to address this dilemma is to start with the assumption that perishability can be represented through higher ton-mile rates, but that in all other aspects perishable goods are the same as non-perishable ones. This is, of course, largely what we experience in real life where the monetary cost of shipping is proportional to both weight and speed: overnight shipping of premium cuts of beef from Nebraska to anywhere in the world is always possible[3]...provided that we are willing to pay for it. If we have two equivalent goods—one produced locally, and one

[3] See http://www.kansascitysteaks.com/ or http://www.omahasteaks.com/ for instance.

being produced far away—and it still makes financial sense to 'ship in' the distantly-produced competitor, then it must be the result of cheaper inputs of materials and labour. However, the additional transport costs must be low enough to still allow for competitive pricing in the final market. In other words, global supply chains are a symptom of the reduced importance of shipping costs as a proportion of a product's total cost.

However, to make such structures work requires coordination on a global scale, making it obvious how the opportunity for the global logistics firm emerged in the 1970s and 1980s. Only the logistics firm is able to reap the economies of scale required to keep global transportation costs at a manageable level while also delivering goods in the timely fashion required to support the 'survival of the fastest' (Toffler, 1990, in Kasarda, 2000a, p.3). Rising fuel costs in 2008 dramatically altered the index of production for many firms, and in some cases manufacturing was brought from Asia back to North America (Rohter, 2008).

Ubiquitous Resources

One factor in Weber's model that is often overlooked concerns the availability of 'ubiquities' and their influence on ideal firm location. Ubiquity "means that the commodity is so extensively available within the region that, wherever a place of consumption is located, there are either deposits of the commodity or opportunities for producing it in the vicinity" (Weber, 1909 [1969], p.51). In other words, ubiquitous resources are available in a given area in such abundance—either in absolute terms or relative to other possible sites of production—that their use by firms is what economists would term non-rivalrous and non-exclusive.

Ubiquity & Location: The effect of a ubiquitous input on firm location varies with its role in the production process. Taken to extremes, a manufacturing firm that used only ubiquities to produce its goods would seek to locate at the place of consumption since only the finished product has any kind of weight to ship (1909 [1969], p.62). A more concrete way of thinking about this aspect of location is the case of hydroelectricity: production has a strong dependency on fast-flowing bodies of water and so these exert a powerful locational pull on electricity producers (1909 [1969], p.89–94). In contrast, the actual output of the generation process is easily shipped via power lines—though there are large losses over long distances—and so normally has a negligible impact on the locational decisions of final consumers.

There *are*, however, some interesting exceptions: for instance, for data centre and web hosting providers the geography of telecommunications infrastructure may seem an obvious dependency, but rather surprisingly we also find that proximity to a large, reliable power supply is an increasingly important factor as well (Economist, 2008c). In 2006, the growing energy demands of the code-breaking computers at America's NSA nearly overwhelmed its power infrastructure entirely, leaving it unable to monitor global communications (*ibid.*). Recently, both Microsoft and Google have opted to locate data centres near hydro plants in order to secure reliable access to affordable power (Economist, 2010e).

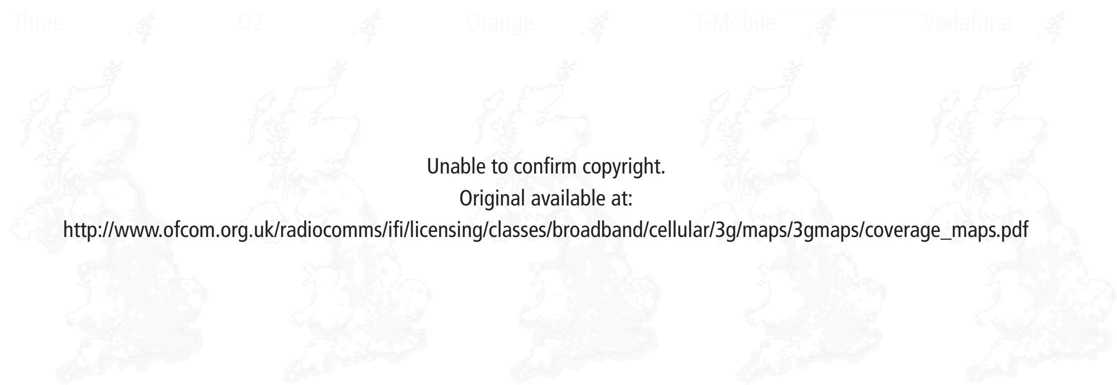
Equally, it may seem unlikely that anyone today would much take the type and bandwidth of local telecommunications into account: small firms are unlikely to saturate even the most basic retail broadband connection, and larger firms normally expect to lease extra capacity directly from a telecoms supplier without moving to a new facility. But where specific dependencies arise, the freedom of location on digital networks may tighten dramatically: a British film production or postproduction company wishing to collaborate with a Hollywood studio still has little choice but to maintain a facility in central London so as to have access to SohoNet for real-time editing (Nachum, 1999, p.27).

Figure 3.3: SohoNet Services Area (SohoNet, 2010)

Quite simply, there is no way to deliver 100Mbps or more of point-to-point dedicated bandwidth between users—something that SohoNet boasts (2008)—over public networks. Since SohoNet is privately-held and demand-driven, the map of SohoNet-enabled cities essentially reflects a geography of the willingness of film-related firms to pay for premium network services, and it points rather strongly towards a specific global distribution of film production (see Figure 3.3). What is particularly interesting about this figure is that it not only reflects the continued centrality of London, and even more prominently of Los Angeles, but that it also indicates the increasing importance of production functions at subsidiary centres such as Vancouver (cf. Scott and Pope, 2007).

Gorman and McIntee (2003, p.1169) have argued that the 'new urban hierarchy' of wireless infrastructure "provides opportunity for peripheral locations to gain connectivity." This may well be true in a general sense, but the point I would like to emphasise here is that we should not forget the forces operating at the margins of even such theoretically placeless technologies as mobile telecommunications. Figure 3.4 demonstrates that place still matters a great deal when you want to access the latest in wireless infrastructure: if your firm depended on high-speed wireless data access then it would certainly be wise to base yourself in the South East or Midlands, and your choice of operator would be much more tightly constrained than you might initially expect.

Ubiquity & Demand: Again, these newest networks are privatised, and so the pattern of deployment is a function both of demand concentration and of wealth, so it is hardly coincidental that Vodafone's trials of hsupa (High-Speed Uplink Packet Access) occurred in business environments—central London, and in particular the City of London, and at international and regional airports—where business demand accumulates in high densities (Ray, 2009). In the same way, we may anticipate that the long-awaited deployment of new networks such as WiMax, and its Korean sibling WiBro (Economist Intelligence Unit, 2006, p.69), will begin in urban areas, and not in the rural areas that are most in need of long-range, high-speed wireless access.



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Original available at:
http://www.ofcom.org.uk/radiocomms/ifi/licensing/classes/broadband/cellular/3g/maps/3gmaps/coverage_maps.pdf

Figure 3.4: 3rd Generation Mobile Coverage (Ofcom, 2009)

The issue that we have not yet addressed is whether we can treat information as a material input like any other. And following naturally from this: can information be transported from one place to another? If so, does it have a weight? Or a transport cost? Drawing on the findings from Chapter 2, we might initially expect that the geographical distribution of information would cease to exert much in the way of a locational pull on industry: data accessible from anywhere renders place irrelevant. However, consider first that location is unimportant *only* if all types of information can be effectively communicated electronically; and consider too the fact that a great deal of information processing is still done by people. Where the people who handle information have unique skills, then the firm's ability to access this resource will still matter a great deal.

Agglomeration & Technology

Agglomeration: We cannot understand today's concentration of financial firms on Wall Street and in the City of London without reference to these places' proximity to major ports of transoceanic shipping that functioned as 'entrepôt towns' that gave traders early access to the 'supply' of information coming from docking ships (Vance, 1970, p.149). And Meier (1962, p.43) makes the point that "opportunities also appear at linkage points in communications systems and entrepreneurs located there obtain access to several independent sources of information first." But when information has to be physically transported, then the consumers of time-sensitive data are constrained by a prohibitively high ton-mile transport cost. A similar dynamic once affected the producers of information: Haig (1926b, p.425) notes that newspaper printing needed to be centrally located because "a central location is convenient from the point of view of the assembly of the news."

Over time, technological change has altered these requirements: the presses themselves have been moved to cheaper locations, leaving only the reporters and management downtown; and today it seems that even the writers are no longer strictly required to be based in Mid-Town New York or on Fleet Street since Schifferes (2007) reports that writers are now covering U.S. financial news from Bangalore. So the introduction of telecommunications networks as an alternate channel for the delivery of products and services breaks the historic link between distance and time (Graham and Marvin, 1996, p.117). In as much as information is available instantaneously online, it seems difficult to conceive of this factor as having a ton-mile 'cost' for firms.

However, the recent furore surrounding high-speed/high-frequency trading by the largest brokerage and investment firms serves to highlight that, as with power, in some extreme cases it does still matter: access to the server rooms where the electronic markets actually operate and to the computing resources able to exploit a millisecond-sized trading window can still make a difference (Duhigg, 2009; Stokes, 2009). However, even where these extreme performance requirements are lacking, we still find bankers in London citing the importance of data providers in determining where they want to locate (Cook et al., 2004, p.12).

The point is this: when transport speeds could be measured in the tens of kilometres per hour, then network and geographic distance were largely equivalent. Without a phone, entrepreneurs "cannot communicate faster than they can walk" (Economist, 2007c), but the introduction of digital and upper-tier infrastructures changes this equation because within-network distance counts for much more thanks to the massive spatial discontinuities that they create: "as far as the Internet is concerned, the fact that Carnegie Mellon University and Lycos are 14 hops away is more important than that they are four miles apart" (Burch and Cheswick, 1999, p.98). And as we argued in Chapter 2 this issue is not only limited to the Internet infrastructure, it applies to all of the increasingly sophisticated systems upon which we depend.

So by positioning themselves at points with ready access to global networks, multinational enterprises and other providers of advanced goods and services are actually lowering their 'ton-mileage' rates even when they operate from seemingly high-cost locations. In fact, it may be in part the cost of these new networks that drives firms to locations where it can be spread amongst as many companies and organisations as possible. And of course, agglomeration also produces savings for firms that are investing in plant since specialised technical equipment can "be taken out of the single large plant and [made to] work for several of them, *i. e.* become the basis of independent auxiliary industries" (Weber, 1909 [1969], p.129)[4].

[4] For Weber, agglomeration also had a strong social flavour and this could play an important role in explaining persistent regional variations in labour productivity (1909 [1969], p.22). Weber excluded this issue from further consideration on the basis that it was a 'particularity'; however, for contemporary firms, especially in sectors such as entertainment, local culture is increasingly seen as a raw 'material' (cf. Scott, 1997).

Technology: For Weber, the importance of technological change lies primarily in its ability to alter the ways in which factors of production are used, and in the costs incurred in transporting those factors to the factory (1909 [1969], p.129). So if a process that once required ten tons of iron ore as an input now only requires five, then the total effective cost of that input has been halved and the other factors have become relatively more important. Conversely, a 50% decrease in the cost of moving all raw material around would translate into a halving of every factor's cost to the firm, so unless this brings into play new options in terms of inputs and outputs it should produce no real change to the firm's optimal location.

But a doubling of the distance over which inputs are shipped *does* change the ease with which the firm can coordinate the transport of goods or services since, historically, agglomeration enabled firms to "remain 'in touch' with one another" (Marshall, 1890 [1948], p.189). So, colocation of partners or units within a firm generally creates savings on the cost of organising transactions (Grabher, 2002, p.209), and improvements to communications improve the ease with each part of a production process can be coordinated with the next. This would enable research and development, manufacturing, and marketing divisions to seek out different points of least transport (*i. e.* lowest ton-mile cost) and maximal labour benefit (*i. e.* best labour index) while remaining in close contact.

Spatial Implications

In finance, the shift from actual trading floors to virtual ones (Weidner, 2006), as well as to electronic trading platforms (Kharouf, 2002), frees brokerages to use locations that are quite far removed—by historical standards—from the physical trading floors and exchanges that they replaced (Engelen, 2007, p.1318). So if distance is no longer strictly relevant, then information in the era of digital telecommunications would seem to be more like a Weberian ubiquity than a localised input. Using this approach, we could argue that firms which use information as an input and deliver it as an output would be free from the interlinked historical constraints of distance and time. This is, in fact, exactly the dynamic that Cairncross (1997) was highlighting when she coined the term 'the death of distance'.

However, remember too that this consequence presumes that firms have no other inputs, outputs, or dependencies. This critical point often seems forgotten in the rush by 'technologists' to evaluate the impact of the telecommunications revolution on patterns of human activity. If the transport cost of information tends towards zero, that only implies that other location factors will become correspondingly more important to the firm. Removing one production dependency does not remove them all, it simply alters the applicable production and labour indexes.

At the limit, a firm that relied solely on a particular type of skilled labour and on ubiquitous data in its production process should be willing to 'deviate' over almost any distance in order to access the right labour pool. In Weberian terms: the labour index would tend to infinity. Software development provides a particularly good case study: in effect, multinational firms like IBM have established facilities in India to take advantage of the lower cost of skilled labour in cities like Bangalore and Hyderabad, and of the negligible cost of shipping the resulting source code around the world (Lohr, 2007).

Summary

Lösch (1954 [1973], p.27) has argued that Weber's model was fundamentally flawed by the assumption that factory location had no effect on demand, and we began this section by noting some other important issues with this approach to location. However, as it becomes nearly as easy to move around the world as around town, it is worth asking to what extent global markets function more like Weber's model than they do like Lösch's? In fact, Weber's analysis of industrial location proves surprisingly resilient to the transition to an information-driven economy, and we have shown that the concepts of both transport uniformity and ton-mile shipping costs can be adapted fairly easily to the 21st Century, not least because the ton-mile is—at heart—functionally equivalent to the economic cost of transport considered in Chapter 2. However, we have also noted the rather important caveat that we should think in terms of network distance rather than geographical distance, because the conjunction of advanced telecommunications and upper tier infrastructure mean that we can no longer treat the world as a plain.

We have briefly touched on the way that technology and communication might be changing the way in which production itself is organised. Traxler and Luger (2000, p.284) summarised the activities of firms as follows: "[they] try to find optimal locations for parts of the production process and cooperate to minimise risks/costs…" The notion that the production process is divisible is hardly new: although Weber typically treated the firm as a point in space, he recognised that it was not necessarily an 'atomic' entity, and that production could also be treated as a series of discrete steps in separate facilities (1909 [1969], pp.128–129). L'Harmet (Bellet and L'Harmet, 1998) shows how this change transforms the firm into a network of interconnected processes, each with its own costs and locational logic.

In much the same vein, Haig suggested that we think of the company as a 'packet of functions' which, as it changes over time, also changes the firm's spatial requirements (1926b, p.418); he notes that:

> Fabrication as a function by itself gains nothing from being located on high-priced land. But in the industrial packet there are other functions in varying proportions, which do gain materially because of the contacts afforded by the central sites. The industries that are leaving Manhattan are those in whose packets these other functions are relatively unimportant.
>
> *Haig, 1926b, pp.426–427*

However, Haig went further than this, and he explicitly connected agglomeration in the CBD to the flow of information ("transportation of intelligence") within firms and between firms (1926b, p.427). And if we look again at Table 3.1 on page 86 then we see that many firms *still* rate proximity to others (and especially to customers) highly. But if telecoms were truly making information a ubiquity then why would this be the case? And while the new virtual trading floors are some distance from the physical ones, we still find financial firms in very close proximity to one another.

Table 3.2: Sectoral Aspects of Information Usage†

Information as Input	Information as Ubiquity
Financial Services	Software as a Product
Personal Services	Call Centre Operations

†Here we force sectors into one category or the other, though as we will see later there is really a continuum of informational usage.

In short, we have some cases where information behaves like a localised input exerting an important effect on firm behaviour, and others where it resembles a ubiquity. But why is this the case? And what are the characteristics of the information being employed that cause it to behave in one way or the other? Our review has already encompassed examples from several different sectors, and I have listed them in Table 3.2. Accounting for this dichotomy is the challenge of Section 3.3.

3.3 *Theory of Markets & Risk*

The explanation that I will put forward is that we need to understand the spatial behaviour of sectors in the context of market opacity. Weber's model is quite straightforward in its treatment of markets: implicitly, it is possible, and even quite easy for a firm to price inputs—whether material or intellectual—from different sources and to determine prevailing prices in distant markets. However, the model fails to account for the distribution of information, both in terms of the means of distribution itself and in terms of the distribution of the information needed for pricing a transaction or contract.

Vance (1970, p.156) has already connected information access to market structure, noting that it will spread further 'along the lines of best intelligence flow'. However, a more extensive analysis is set out by Clark and O'Connor (1997) who argue that the spatial preferences of producers of financial products are connected to the varying levels of informational 'content' in financial markets. My intention here is to demonstrate that their approach is relevant to *all* industries, and that it brings us closer to an underlying issue identified by Coase (1937, p.398) which is that the firm does not exist solely as a result of the division of labour, but also as a means of managing risk and uncertainty.

Market Opacity

Financial products make a particularly good case study because they are immaterial and information-based. So if we find aspects of firm behaviour here which suggest that information is still a locational input, then it is reasonable to suppose that we may find them in many other sectors as well. In fact, this is exactly what we will discover in Clark and O'Connor's (1997) examination of the financial markets, and their grouping into three categories—transparent, translucent, and opaque—based on the informational content of products traded. Empirical support for this tripartite categorisation comes from Engelen (2007) and Faulconbridge et al. (2007a) in their analyses of the decline of trading activity in Amsterdam following the Dutch exchange's merger with Paris-based Euronext.

Transparent Markets: In transparent markets the value of a particular financial product can be easily verified using standard metrics so that "the information needed to trade does not require interpretation" (Engelen, 2007, p.1308). Consequently, trading in transparent markets can be routinised and requires relatively little specialised knowledge or information (2007, p.1308). Mutual funds indexed to market composites such as the Dow Jones Industrial Average or Standard & Poor's S&P 500 index are good examples of this, and transparency also increases the ease with which competitors can enter the market.

What transparent financial markets do require is scale: the thresholds (liquidity, financing, etc.) for profitable operation in a transparent market will tend to limit operations to only the very largest, global exchanges (Clark and O'Connor, 1997, p.103). These enormous volumes are necessarily underpinned by sophisticated and expensive trading platforms, as well as skilled personnel (1997, p.101), so the market for the underlying systems is surprisingly small and may extend no further than the three global hubs of Tokyo, London, and New York. In contrast, on the consumer side the movement to digital trading systems enables trading to happen from afar, so the retail markets are very large indeed.

Opaque Markets: On the other hand, opaque markets "have a low level of standardization, and are small in number, small in size, illiquid, and hence risky" (Engelen, 2007, p.1307). In an opaque market information is much more likely to be distributed asymmetrically (Clark and O'Connor, 1997, p.98) and there is an element of trust that the seller has correctly assessed the risk embodied in a derivative or other complex instrument[5]. The inability of such products to scale and the unique features of each product mean that opaque markets appear to place a premium on local, often un-traded information as a way to mitigate the level of risk involved in such investments.

[5] Or, in some cases, trust that they are not betting against the product that they've just sold you (Morgenson and Story, 2009).

Real Estate Investment Trusts (REITS) and algorithmic trading systems are two examples of opaque products (Clark and O'Connor, 1997, p.99)[6], but the turmoil in the derivatives market as a result of the 'subprime mortgage crisis' serves to illustrate the point more effectively. Opacity in the underlying mortgage market results from the fact that each mortgage is unique and that knowledge of the real level of risk for any one loan is quite poorly distributed. So, historically these products were managed by community-based banks with detailed knowledge of the local context such as the borrower's financial history, the regional housing market, and so on.

[6] Although the latter trade predominantly transparent products such as stocks and foreign exchange (FX) their workings are based on the application of highly-sensitive computing resources. And while the scale of turnover—an average of $1.2 trillion per day for April 2001 (Clark and Thrift, 2003, p.7)—might suggest that this is an entirely transparent market, what we seem to see here are firms creating ways to make some aspects of its operation largely opaque.

From the mid-1990s, mortgages began to be aggregated and sold on to national and global investors in collateralised debt. Crucially, this process depended on the assumption that the degree of risk had been mitigated through the use of statistics to create seniority tranches with well-defined risk profiles. Unfortunately, this approach overlooked two key issues: first, that the models might fail in unusual market conditions; and second, the growth of conflicting incentives: mortgage originators had little or no money at stake in the event of a default, but could reap enormous rewards for sourcing large mortgages from less creditworthy households. The failure of the former has led Economist (2010a) to assert that the "financial crisis may the first major crisis of 'big data', but it will not be the last."

The pervasiveness of Collateralised Debt Obligations (CDOs) as a financing and investment vehicle, along with their endless repackaging into new products, meant that it was difficult to know who was on the hook and for how much in the increasingly likely event of a default. The degree to which the mortgage market remains fundamentally murky can be inferred from the fact that by the end of 2007 Goldman Sachs was valuing each dollar's worth of its mortgage securities at 67.5¢, while other firms still carried them at 90¢, an astonishing divergence "among traders who are all supposed to be sophisticated" (Cohan, 2010).

What is particularly interesting about the ensuing carnage is that it reveals the extent to which opaque markets are still deeply rooted in trust between both individuals and firms. The spread of mistrust nearly brought about the collapse of the entire financial system: bankers simply did not believe the statements being made by trading counterparties and sought to reduce their exposure to this market and to shore up their own balance sheets as quickly as possible. The deleveraging process had significant collateral impacts in the financial sector—leading directly to the nationalisation of Northern Rock (Economist, 2007a)—but also for businesses far from the property market. We will return to the issue of trust in Chapter 5.

TRANSLUCENT MARKETS: Lying on the continuum between transparent and opaque are translucent markets; here, products acquire "particular characteristics [that] are deliberately designed by institutions to be different from the standard, industry reference product" (Clark and O'Connor, 1997, p.96). The degree of translucency can be actively managed, and this manipulation need not be malign: a valuable service is performed by intermediaries that effectively 'move' products from one type of market to another by repackaging them as a tradeable asset (Engelen, 2007, p.1321). So firms engaged in the production of translucent financial instruments are converting "opaque assets to easily recognisable and tradeable properties (risk, return, liquidity) and [enabling] the construction of higher-order assets using these properties as building blocks" (*ibid.*).

Integral to the functioning of this market are the credit rating firms who, as Sassen (2002, p.23) puts it, "turn 'interpretation' into 'information'". The rating firms do not themselves take positions in the products that they rate, but they enable other firms to do so: in the bond market, the monoline insurers use their own, and the raters', inputs to determine whether to act as guarantors of the opaque assets being offered for sale. The monoline firms effectively loan their AAA standing to municipalities issuing bonds; this is a fairly low-risk and low-return market, but one that is well-understood and where returns come largely from scale. However, these insurers eventually diversified into the more exotic market for CDOs (Economist, 2007b, 2008a), enabling opaque debt to be sold on in products purportedly suitable for institutional investors such as banks and funds.

Clark and O'Connor (1997) link each market type to a spatial scale (see Table 3.3): transparent financial products will be distributed through the largest exchanges so as to take advantage of greater liquidity, while opaque products will generally be created and sold locally. Meanwhile, on the purchasing side transparent products can be effectively procured from anywhere in the world through standardised trading systems, significantly loosening the bonds of proximity, while opaque products cannot, and so are likely to be obtained through shorter chains of buyers and sellers with connections to the originating market.

	Transparent Products	Translucent Products	Opaque Products
Market Scope	Global	National/Transnational	Local
Agents	Global Financial Institutions	Hedge Funds/ Specialised Traders	Local Brokers
Example	Gold, Blue Chips, Foreign Exchange (FX)	Credit-based Derivatives, Asset-backed Securities, Futures	Private equity, Commodities, Shares of Small/Mid-Cap Firms

Table 3.3: Opacity Characteristics (after Clark and O'Connor, 1997, p.99 and Faulconbridge et al., 2007a)

Table 3.3 enables us to refine Weber's locational theory by mapping ubiquitous and localised informational inputs on to the typology of transparent and opaque markets. We can turn to the introduction of the telegraph—sometimes referred to as 'the Victorian Internet' (cf. Standage, 1998)—for an example of how changes to the transparency of a market may play out in practice. The telegraph network spread out across the Eastern Seaboard, and in particular along the Erie Canal and towards Chicago, but Figure 3.5 (on page 97) neatly illustrates the central role that New York City played as the place where goods and information were gathered from across America and transmitted into global relationships via "Steamer[s] Atlantic bound for Liverpool" (Barr, 1853).

Vance (1970, p.97) set out a fuller discussion of how this 'alignment' was driven by the geographically 'fortunate' combination of New York's position at the intersection between navigable rivers and canals, and an oceangoing trade across the Atlantic enabled by an ice-free harbour (Townsend and Moss, 2008, p.25)[7]. However, in the age of clippers and steamships a message could easily take more than a week to cross the Atlantic, and more than 45 days to reach Australia from Britain (BBC, 2005c). The arrival of the undersea telegraph cables radically changed all this, with messages now taking just 24 hours to be relayed to anywhere in the world that was served by a submarine or overland cable (*ibid.*). Such was the demand for transoceanic communication, that the first reliable link between between Porthcurno, Cornwall and America did £1,000 worth of business on its first day of operation (BBC, 2005c), roughly £60,000 in today's terms (National Archives, 2006).

[7] The growth of entrepôt cities like New York also provides a mechanism for economic development that is detached from the organised hierarchies of Christaller's central places (Vance, 1970, p.85); in that sense I believe that it represents a more robust model for urban growth that accords well with Jacobs' 1969 equally radical approach to 'cities in civilisation'.

Figure 3.5: Telegraph stations in the United States, the Canadas & Nova Scotia (Detail from Barr, 1853; reproduced with permission)

Unsurprisingly, brokers and speculators were the first to make 'early and avid use' of the telegraph because it "allowed small time delays to be exploited…for profit, by entrepreneurial capitalists" (Graham, 2004, p.44). But the ability to relay this information quickly and easily across the country also provided an important impetus to the centralisation of commodities and securities markets; indeed, the very existence of Wall Street seemingly owes a great deal to the impact of the telegraph in the period between 1850 and 1880. The increased circulation of pricing information made it more efficient (and competitively advantageous) for traders to exploit New York's position as an entrepôt for both goods and information heading inland or overseas (Tarr, 2004, p.45).

I would like to point out, however, that this typology of transparency need not be limited to financial markets alone. To boil it down to the bare minimum, opacity is simply a measure of the ease with which information about a product circulates in the market and, as such, can be applied to any market, and the trade of any entrepôt can extend outwards as far as the limits of commercial intelligence (Vance, 1970, p.156). In the case of financial markets it is information about the price of commodities and securities whose circulation affects the incentives for centralisation and dispersal, but we can just as easily compare other markets in this way: the market for software (especially as it concerns the distinction between software as a service and an off-the-shelf product) or the market for healthcare (especially as it concerns the pricing of services) for instance. In each of these cases, the market and prices for opaque goods and services are characterised by smaller overall scales and higher levels of uncertainty with regards to value.

Uncertainty & Risk

The market modelled by Weber becomes significantly more complex with the addition of opacity. What the preceding section sought to make clear is that there is an important connection between opacity, uncertainty, and risk. Technically, there is "a distinction between risk, which can be assessed in terms of quantifiable likelihood, and uncertainty, where probabilities cannot be attached to possible outcomes" (Gray, 2009, p.13); so although I will tend to use the uncertainty and risk interchangeably for stylistic purposes, I wish to note that they are *not* the same. However, using this formal definition it should be clear that in transparent markets there is always risk, but it is broadly understood and truly unexpected shifts are rare, whereas in opaque markets there are basic uncertainties *in addition* to risk.

The Boundary of the Firm: The interaction between information and space means that some degree of uncertainty now intrudes into every action undertaken by the firm: buying, selling, expanding, and diversifying. As a result, there are hidden costs to employing the market as a coordination tool: the cost of discovering the relevant prices for a good or service; the overhead of negotiating pricing and delivery; and the management of contracts (Coase, 1937, pp.390–391)[8]. The firm can address these costs by internalising those steps that are most vulnerable to failure, so the degree of vertical or horizontal integration of a firm is a measure of how far it will go to suppress 'the market' for a good or service upon which it depends (1937, p.389). However, the firm must now manage functions or inputs that, in an optimal environment, could be secured more efficiently in an open market where greater economies of scale and competition prevail. In short, as the firm grows it may actually become less efficient.

[8] In addition, cultural and institutional variations at the level of regions or nations can lead to greater or lesser degrees of uncertainty: the Economist (2010f) suggests that the size of Tata Holdings in India is directly related to a lack of trust in the institutions that manage markets

Coase (1937, pp.395–397) summarises the interaction between risk and cost as follows: the firm will tend to grow if the cost of organising transactions is low and these costs increase slowly with the number of transactions; the firm will also tend to grow if size reduces the likelihood of 'mistakes' (*e.g.* through an ability to research the market or plan superior products) or the probability of a mistake only increases slowly with the number of transactions; and finally, the firm will also tend to grow if increases in the scale of production also enable it to benefit from lower prices for inputs. This does not mean that the firm's transactions are homogeneous, and firms that diversify or deal with many suppliers may find that both costs and mistakes increase with the dissimilarity of its transactions.

In sum, the boundary of the firm is determined by the point where the marginal benefits of internalisation are offset by the marginal disbenefits of expansion:

> A firm will tend to expand until the costs of organising an extra transaction within the firm become equal to the costs of carrying out the same transaction by means of an exchange on the open market.
>
> *Coase, 1937, p.395*

In this same vein, Scott (1986, p.219) notes that "the line that divides the internal hierarchy [of the firm] from the external market…is fixed at the point where the relative efficiencies of managements and markets are equal." And the probability of mistakes increases with firm size because it becomes increasingly difficult to coordinate activity (1937, p.397). The point where these tradeoffs emerge varies by industry since both uncertainty and risk differ from sector to sector (Coase, 1937, p.395).

Search, Implementation & Experience Issues: Although a transaction between firms can take many forms, Charlot and Duranton's model of a two-stage project with 'search' and 'implementation' phases enables us to elaborate on how risk and uncertainty can vary with the market (2006, p.1368) and impose spatial costs on the firm. The search phase identifies suitable partners for a subsequent implementation—whether the installation of a piece of hardware or the establishment of a scientific collaboration—while the implementation phase is 'simply' its execution; note, however, that the benefits of the 'transaction' must exceed the *combined* costs of both phases for a project to be considered worthwhile.

Different products and industries obviously have different balances between the two types of costs, leading to different communications tradeoffs (Charlot and Duranton, 2006, p.1383). In general, the search phase in a transparent market should be relatively less expensive because comparisons can be readily drawn between competing products, while the search phase in an opaque market will be longer and involve greater effort because features may be more difficult to compare. Moreover, these costs may also be encountered with varying frequencies: in a recurring context even modest search or implementation costs may add up quite rapidly, so anything that improves the likelihood of a successful match between buyers and sellers will prove a major competitive asset.

We can connect this approach to the more traditional distinction between 'search' and 'experience' goods. Search goods have qualities that can be easily assessed—a computer chip's clock speed or a book's price—while experience goods such as an education or a consultancy's advice reveal their true value through 'use', typically over an extended period of time. Following Charlot and Duranton's model, we expect experience goods to have both higher search and higher implementation costs: they are more difficult to compare in the first place, and there is an increased likelihood that usage will reveal a significant failure. Anything that decreases the probability of a successful outcome increases the relative cost of searching.

The success of web sites such as Amazon.com and Ebay.com—firms without any kind of physical shop-front at all—suggests that many people have comparatively little compunction about sourcing search goods from far away. This aspect of transparent markets may help to explain why early thinking about e-commerce was so wildly off-base: there were those who anticipated using Virtual Reality (VR) goggles to explore virtual aisles and dress avatars designed to show us what we might look like wearing our chosen attire; and there were those who expected the online market to be limited largely to those confined to the home by illness, or unable to make it to the shops because of work-related commitments (cf. Graham and Marvin, 1996, pp.155–156). Instead, the experience of online shopping is much less sophisticated, but the market is vastly larger.

However, the growing prominence of user reviews on sites such as TripAdvisor represents something altogether more interesting. Using the terminology of opacity, we can think of such sites as creating a translucent market where only opacity existed. In particular, cultural products are "about taste, not performance and so, unlike a dishwasher or a computer or even a car, there is no method or even means to evaluate how well it performs" (Currid, 2007, p.4). Cultural artefacts such as books, films, and music may be opaque to the extent that we have difficulty determining which symphony or director is 'best', but they are also transparent to the extent that once we have made a choice of performance we can also source the tickets or recording from anywhere[9].

Telecommunications enables "information about search goods [to] be provided on the Internet in a more accessible, less costly, and more customizable way" (Weltevreden et al., 2005, p.68), and we can see how this will affect the boundaries between transparency, translucency, and opacity. However, telecommunications is also unlikely to affect the most complex experience-oriented purchases except in as much as it creates ways of improving the implementation phase (*e.g.* distance learning or the simulcast of live opera into movie theatres[10]). So while we might expect that online 'classrooms' create new ways for universities to compete in the continuing education field, the creation of campuses in China and the Middle East by British and American institutions suggests that many such complex goods and services still require a good deal of effort in implementation.

[9] The opacity of cultural goods means that their value is largely contingent upon *experience*, and so it is preferable to purchase them using mechanisms that short-circuit the search process. Recommendations from others are a good way to improve the odds of a successful match, but working out who to 'trust' can be a time-consuming and cognitively costly process (this was the function that an 'aggregator' of reviews such as Zagats or the Good Food Guide served). Instead, the tools that enable Amazon, TripAdvisor, and other web sites to offer increasingly accurate recommendations are made possible by what Economist (2010c) calls 'big data', in which our own actions are used to find and feature recommenders who 'look' like we do, and to make recommendations based on people who 'act' like we do. Behaviourally-driven recommendations encourage us to complete the purchase of a good that we might previously have insisted on handling or listening to in-person.

[10] Interestingly, this latter example harkens back to the 19th Century's Electrophone subscription service, which used the phone system to pipe live music into subscribers' homes (BBC News, 2010).

Agglomeration & Technology

Agglomeration: Ultimately, inventions that bring a firm's factors of production 'closer together' will increase the maximum size of a firm by reducing the costs of spatial organisation and degree of risk (Coase, 1937, p.397). Linking the notion of opacity back to the study of infrastructure in Chapter 2, we can see how buyers and sellers in opaque, complex, and uncertain markets will prioritise access to networks that reduce perceived distance. Clark and Thrift (2003, p.15) note that in the Foreign Exchange (fx) market, "under conditions of uncertainty, traders bunch together at…[particular] moments in time and space for more information"; crucially, Clark and Thrift do not specify whether this proximity is physical or virtual since both types have value for fx traders.

The link between various types of proximity and the improved management of risk and uncertainty may help to explain why we have historically seen increases in both telecommunications usage *and* business travel—it is the conjunction of the two that enables firms to bridge the problems inherent in long distance interactions, and not either mechanism in isolation. However, the extent to which some form of proximity is required varies with the degree of opacity of the market: firms operating in opaque markets will tend to require more proximity *in general*, while those operating in transparent markets will need less of *both* physical and electronic proximity.

As a result, firms in transparent markets will generally experience greater freedom of movement. Developments that improve transparency of a market and lower search costs by, for instance, improving the ability of the firm to determine the relevant prices for inputs or outputs, or reducing the cost of contracting and coordination, are all likely to affect the range of suitable locations for a firm. So *one* outcome of the impact of telecommunications is larger firms with more widely distributed production facilities that remain nonetheless tightly integrated and controlled from headquarters.

Technology: Putting this all together, we can see telecommunications will have a disproportionate impact in markets where information circulates easily. In particular, we would expect to see enormous changes for search goods in transparent markets where the nature or quality of the product does not vary with its source. It is this ability to buy from anywhere and sell from just a few accessibility-favoured locations that allows the contemporary retail firm to try to offer "everything from books and electronics to tennis rackets and diamond jewellry" (com, 2009). The consequences of this change should not be underestimated: the degree to which customers are willing to purchase dvds, books, or clothing online has important implications for retail in city centres (Weltevreden et al., 2005, p.67). Table 3.4 provides an overview of how we might expect different combinations of search and implementation costs to affect the behaviour of firms.

Table 3.4: Expected Impact of Telecommunications on Transactional Cost Structures

		Search Costs: High	Search Costs: Low
Implementation Costs	High	Telecommunications likely to have minimal impact as the transactional cost is still extremely high with little advantage to distance-enabling technologies.	Although ease of searching will increase competition, the high cost of implementation will encourage a reliance on accessible providers.
	Low	The lower cost of implementation may enable more distant competitors to bid for business, but intensive selection methods (RFPs, etc.) and word-of-mouth are still likely to apply.	Radical reduction in search costs and minimal implementation costs would be expected to encourage intense price-oriented competition on a larger scale.

Where market opacity implies that information is poorly-distributed, then we may anticipate that the telecoms 'revolution' will have rather less impact. That said, it is difficult to deterministically link any one technology to a spatial outcome: the phone may lower the risks of internalising transactions through improved coordination, but it may also decrease the cost of organising transactions in the market (Coase, 1937, p.397). The location selected by a firm depends on the 'field of possible locations defined by current technology', and so improvements in transport and communications technology can enlarge that field in significant ways (Vance, 1970, p.131), but the key point is that these may also generate effects within the firm that counteract this nascent flexibility.

Spatial Implications

The Economist Intelligence Unit (2006, p.58) suggests that in the coming decades, labour-intensive, high-volume, and cheap-to-ship products (especially those where the consumer in price-sensitive) will be produced almost exclusively in low-wage countries, while small volume, capital-intensive goods that are difficult to ship will continue to be produced in developed countries. However, if we draw together the two-stage—search and implementation—transaction and the concept of market opacity, then we can make some additional predictions about how firms will use space. In transparent markets, the tradeoffs between potential parties can be assessed from a distance, making telecoms a viable substitute for direct interaction during the search phase. In opaque markets, the importance of localised knowledge is likely to make for more complex searching and implementation phases for which technology may be no substitute and where, consequently, the cost of travel may be a major factor in locational decisions.

The conclusion reached by Clark and O'Connor (1997, p.89) in their analysis is that 'geography still matters', and that there is no evidence to support the kind of placelessness originally anticipated. In the case of financial markets, Clark and O'Connor (1997) echo Christaller and Lösch when they state that: "Just as with a set of retail centres, where differences in range and threshold lead to hierarchies of outlets, so in the production of financial instruments the hierarchical pattern reflects supply-side considerations" (Clark and O'Connor, 1997, p.103). So this notion of transparency brings us back to market areas but, within limits, we can now frame the market in terms of the informational characteristics of space rather than the physical ones.

As the earlier discussion of the mortgage market (see page 94) should have made clear, opaque markets naturally tend to privilege detailed, locally-available data (Engelen, 2007, p.1309). Hedge and venture capital (VC) funds operate in such an environment and typically work closely with the firms in which they take a major stake. The 'costs' of monitoring investments suggests that funds and VCs will tend to invest in firms to which they have ready access or with which they have some form of prior relationship. Where the opportunity is particularly good but the firm is not nearby, they they may work through syndicates acting as a local proxy (Fritsch and Schilder, 2008).

Although there is seemingly no empirical research into the matter, I believe that we can understand the decision of the 'hedgies' to base themselves in Mayfair in a similar fashion. First, the City of London is *less* accessible than West London for firms engaged in many long-term relationships across Europe and, more importantly, the Atlantic; from Green Park it is just 10 minutes by taxi to Paddington, and 15 more by the express train to Heathrow. Second, West London has greater amenity value for the high-net worth individuals that form both the labour pool *and* the client pool for the funds[11]. And third, while a bank simply would not be taken seriously without offices in the City or in Canary Wharf, the hedge funds had no such specific landmarks towards which to gravitate: a non-London location would have been unappealing for American transplants and a barrier to access by clients and employees, but an East London location had significant drawbacks for non-bank financial firms.

[11] One story—probably apocryphal—related to me by a fund manager suggests that one of the first firms to arrive in London chose Mayfair because "the fund manager's wife liked the shopping in the area". Amenity may also play a role in the presence of major property developers in Mayfair, who are similarly free of the need to be in the City.

Summary

The ability to access or transfer information nearly instantaneously has obviously changed contemporary society in a myriad of ways, but our long association with the land line, the fax, and other forms of telecommunications sometimes makes it difficult to see the just how great their impact on markets can be. So it is helpful to draw on evidence from developing countries in contemporary Africa and Asia where telecommunications access has been, until recently, very limited. The point of these examples is that we shouldn't think of individuals and firms as being passive operators in markets with fixed transparency characteristics, but rather as active shapers of those markets.

The best-known case study is the effect of mobile phone access on the income of Keralan fishermen: during the course of the study, average market prices for fish fell by 4% but average profits per-fisherman rose by 8% because the risk of 'boom or bust' in the supply of fish fell dramatically (Economist, 2009c). Local markets had previously been inaccessible (*i.e.* opaque) while the fishermen were at sea, but using mobile phones they could could access price data in a transparent fashion and determine which port was offering the best price for their type of catch. A similar process is at work in Vietnam, where small tailors, repair shops, and producers use their phones to check on local markets and even document business transactions via SMS (TechReview, 2007).

Widespread usage of mobile infrastructure also creates interesting new business models: Economist (2009c) cites the example of an Indian barber who, by giving up a physical store and using his mobile to schedule at-home appointments with clients, increased his profits significantly. *Google Trader* in Kenya allows buyers and sellers to specify via SMS what goods they require or have available to sell and at what price, effectively aggregating dispersed, opaque markets into a single centralised, transparent one (Economist, 2009d). In these cases telecommunications is very directly substituting for costly journeys on poor-quality infrastructure, replacing them with a level of transparency that reduces the costs to small traders of doing business in a developing country. Another example of mobile communications replacing travel is Eagle (2010), which uses SMSs to distribute 'micro-tasks' (*e.g.* translation) for processing by individuals in remote locations (*e.g.* parts of Africa and Asia), and sophisticated software to assemble the responses into a 'macro-result'.

The above cases all describe situations in which a market was opaque because of constraints on the circulation of pricing data; which is to say that there was seemingly nothing innately opaque about fishing and farming that innovation in the collection and dissemination of data could not address. However, the same is not necessarily true of the financial markets examined by Engelen (2007); in the case of the more specialised products it is not simply a matter of determining the correct price for a good because the complexity of the product's experiential dimensions may make it difficult, or even impossible, to value in an objective way. The importance of trust in such markets makes it a form of 'relational investing' (Clark and O'Connor, 1997, p.98) because the buyer relies on their relationship with the seller as a 'guarantee' of the product's fitness for purpose. In such a context, 'customs and conventions' will play an important role (1997, p.106), and the extent to which these can be created or sustained via telecommunications will be considered in Chapter 5.

3.4 Theory of Spatial Transaction Patterns

We have established in a general way that the firm can be understood as a 'system of economic transactions' (Scott, 1983a, p.235) whose boundary is affected by risk and by the type of market. We can now deepen our appreciation of how the type and distribution of transactions affects the dynamics of firm strategy by examining four dimensions of transactional costs: 1) the degree of standardisation; 2) the degree of integration; 3) the nature of inter-firm linkages; and 4) the role of technology (Scott, 1983a, pp.236–242). For Scott, firms that standardise and integrate stages of production, manage linkages to reduce the risk of coordination or market failure, and employ technology to substitute for workers, will demonstrate a diminished spatial dependency on suppliers.

Of course, the degree to which technology and capital can substitute for labour will vary by industry: logically, it will be lower in creative sectors where the innovative dimension of work is difficult to deskill, and higher in the manufacturing and farming sectors where increasingly complex processes are subject to automation (cf. Strickland, 2007). So while there is scope for large firms to seize control of some types of stable markets, in other industries underlying transactional costs limit the potential for economies of scale and permit the persistence, or even dominance, of small-run, labour-intensive firms (Scott, 1983a, p.236). And this variation can even exist *within* the firm: the same decision-making process may be automated in some cases, and personalised in others, depending on the scale and nature of the transaction under consideration (cf. Haig, 1926b, p.438).

Aspects of Transactional Patterns

Standardisation: The ability to standardise the product, as well as the process involved in its production or purchase, will obviously impact the extent to which firms are able to expand and automate output. Small-scale, customised manufacture—especially if the systems require retooling each time the output changes (Scott, 1983a, p.246)—makes efficient queuing very difficult. Thus the 'high cost of idle capital' and the 'relative adaptability of labour' has historically meant that a lack of standardisation required the use of labour-intensive production methods (*ibid.*)[12].

However, it is helpful to bear in mind that labour can be 'standardised' through educational and normative processes: European animators studied by Cole (2008) employed a variety of resources to develop a common understanding of the work to be performed and of their roles within it. The rationalisation of the animated film industry enables market participants to define 'standard interfaces' (*i.e.* inputs and outputs) that reduce the cost of coordination and allows animators in one country to collaborate with producers in another. In this case, standardisation does not entail a de-skilling of the underlying work, but extends its geographical scope.

The domestic affiliates of multi-national enterprises (mnes) offer another example of this process: according to Nachum and Keeble (2003a, p.180), affiliates and subsidiaries in the Soho advertising sector tend to use resources from different spatial scales depending on the type of interaction. More standardised interactions and transactions, such as financing or management tend to pass through the mne's internal global network, whereas less structured ones, "notably those used as a source of inspiration and creativity" (2003a, p.183), happen locally. So if we define standardisation more generically as a kind of process- or role-based modularity, such as in a set of agreed norms for service delivery

[12] Scott (1983a, p.237) also indicates that, at the sectoral level, we can expect an increase in demand for labour-intensive products to encourage more plants, *not* larger ones, because it will encourage further specialisation and 'vertical disintegration' (of which more in Chapter 4) without a corresponding increase in scale.

or interaction, then the scope of telecommunications' ability to impact even very sophisticated firms becomes obvious.

Linkages: Conversely, where interactions between firms or sectors cannot be standardised, or entail significant communication and co-ordination activity, then they become comparatively costly per 'unit of flow' (Scott, 1983b, p.359). Here, intensity and lack of standardisation—which is to say with high search costs—make the process more expensive for dispersed firms (Scott, 1986, p.224). In more mundane terms, in a volatile or fast-moving environment, the more complex and extensive the set of skills required at the meeting table, then the more difficult it is to manage it all via telecoms.

Scott (1983a, p.241) suggests that there are two types of inter-firm linkages: "the physical flow of inputs and outputs, and the inter-personal contacts required for the purposes of transacting business (including the negotiation of input-output linkages)." Subcontracting is a particularly interesting type of linkage since it is designed to decouple demand from the firm's capital investment: small firms in volatile industries cannot (and should not) take on staff or expand plant to cope with sudden, but reversible, increases in demand. In such markets, Scott argues that producers will tend to be found in horizontally- and vertically-disintegrated production systems because outsourcing reduces their exposure while improving their ability to adapt to fluctuations in demand (1983b, p.360).

But as we have seen, vertical and horizontal disintegration does not come without a cost: the overhead required to manage these external relationships. So where these linkages are small in scale, short in duration, or require a great deal of interaction, they are also very costly. Anything that reduces these costs constitutes a competitive advantage (1983b, p.357; 1986, p.224). For many, it is in part the near-instantaneous increases and decreases in demand afflicting cultural industries—and the concomitant requirement for skills or capacity to be brought on-stream or off-loaded with little or no notice—which account for their tight spatial clustering in major cities (Currid, 2007, p.83). Conversely, large and stable linkages reduce the overheads of a link and may enable more costly linkages —such as those organised over long distances—to become economically efficient. Improvements in communications will thus make deconcentration a viable locational strategy for sectors where this was not always the case.

Integration: In contrast to subcontracting, integration is most likely to occur when there are feed-back and feed-forward effects that propagate through linkages between firms (Scott, 1986, p.221). For instance, in the oil industry it is logical for producers to integrate backwards with the extraction industry so as to suppress the impact of fluctuations in the supply of crude oil (Scott, 1986, p.221). But for large-scale producers of entertainment it is sensible to integrate forwards with distributors so as to suppress demand-side risk by securing distribution channels for output (cf. Scott, 1996, p.316).

For more consumer-oriented goods and services, Robinson (1931 [1943], p.128) argues that integration is likely where firms compete on the basis of quality and recommendations, and so need tight control of the channel and the message that is received by consumers. The implication here for retailers is that firms that produce high-margin, luxury goods are likely to require "…high-quality 'shoptainment' stores that provide personal service and/or an entertainment experience" (Dodge, 2004, p.225). Apple's investment in retail was driven by just such issues: Steve Jobs, Apple's CEO, observes that "people haven't been willing to invest this much time and money or engineering in a store before…It's not important if the customer knows that. They just feel it. They feel something's a little different" (Useem, 2007).

In fact, the Apple Stores now found in cities around the world may well be the best example to-date of this type of integration; they accomplish four things with nearly unprecedented ease: they create an association between Apple and premium 'signifying locations' (which also happen to have a lot of foot traffic) such as Regent Street and SoHo; they communicate a 'brand message' of elegance, simplicity, and refinement; they offer a 'personal touch' in the form of on-site 'Genius' support staff; and they make Apple's products accessible to new users[13]. The result is that even though Apple has less product on display than iconic shops such as Tiffany's, in 2007 the company *averaged* sales of $4,032 per square foot, nearly twice that of the luxury jeweller (Useem, 2007).

[13] A particularly clever touch is the fact that, unlike many retailers, all of Apple's computers are connected to the Internet, allowing users to actually try out the e-mail client, web browser, and other network-enabled software. It can sometimes seem as though half of the visitors to Apple's Regent Street shop are tourists making use of this facility to send free email home.

Table 3.5: Likely Outcomes of Market & Transaction Stability

	Stable Market	Unstable Market
Stable/ Standardised Transactions	Horizontal Integration (Scale Economies)	Vertical Disintegration (Subcontracting)
Unstable/ Unstandardised Transactions	Vertical Integration (Input Management)	Horizontal Disintegration (Concurrent Contracting)

So, on the one hand vertical integration may occur when transaction failures are common "because of information asymmetries and the difficulty of policing contracts and claims in complex environments" (Scott, 1986, p.220). But on the other hand, subcontracting (*i.e.* vertical *dis*integration) may be a rational response when it is the markets themselves that are uncertain because it allows companies to offload risk (1984, p.21). Particularly uncertain markets may even mean that the firm may actually come to rely on potential competitors for excess capacity, using concurrent contracting to meet demand from its own clients. These relationships are summarised in Table 3.5.

Agglomeration & Technology

AGGLOMERATION: For reasons established in Chapter 2, physical concentration reduces the costs associated with travel and the limitations of poor-quality infrastructure (Cook et al., 2007, p.1340). Lower costs increase both the frequency with which meetings can occur, and the ability to set up many meetings in quick succession on short notice (2004, p.31). This capacity is particularly important in complex transactional environments such as those found in the City of London where it is common to require the services of accountants, lawyers, and bankers at the same meeting (2004, p.27).

The extent of the inter-dependencies in the City of London can be gauged from Figure 3.6, drawn from Cook et al. (2004, p.25). The figure shows the percentage of times that staff in a 'source' industry rated firms in a 'destination' industry as being of particular importance to their business[14]. So employees in the Banking and Insurance sector see themselves (and are seen by others) as the focal points of the City of London's financial services agglomeration since they rate relationships with other firms in the *same* sector as being of principal importance. Employees of Fund/Asset Management firms rate relationships with Banks, Investment Banks, and other Fund/Asset Management companies as important, while Accounting staff apparently see little value in their intra-sectoral relationships, focussing almost exclusively on the external ones.

[14] The question was phrased: "Which types of firms do you have the most important inter-relationships with?" (Cook et al., 2004, p.49). We should note, however, that some of these results are based on low sample sizes (2004, p.26).

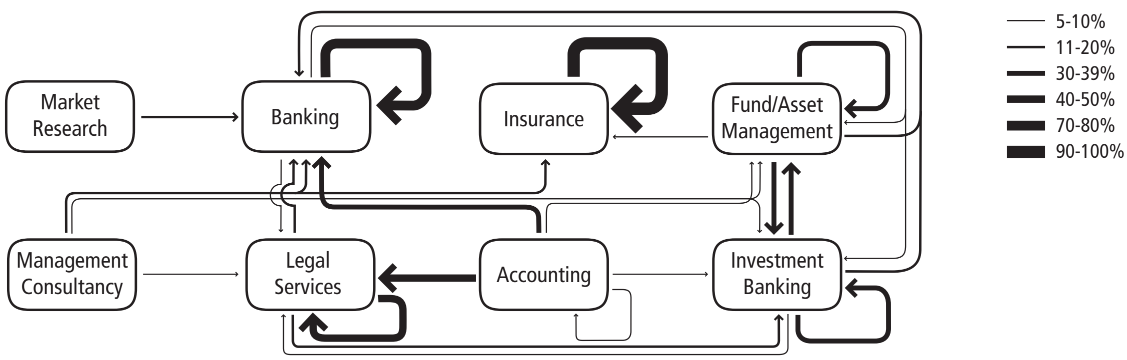


Figure 3.6: Sectoral Dependencies in the City of London (Cook et al., 2004, p.25; reproduced with permission of the authors)

Although the costs—rent, labour, congestion, etc.—of doing business are greater in a big city, Charlot and Duranton (2006, p.1371) argue that the density of firms also increases the likelihood of a successful match during the search phase of a project or transaction. So projects that would not be viable in smaller cities because of the low probability of a nearby match are nonetheless manageable in large agglomerations, and this increases the frequency of successful, complex projects in large cities (2006, p.1370). Clearly, the key here is the concentration of firms and not population *per se*, so agglomeration need not occur in the Central Business District (CBD) for firms to benefit from more efficient matching mechanisms (Scott, 1984, p.25).

Improvements in technology reduce the cost of travel to more distant partners, representing an increase in the effective area over which agglomeration processes can occur. The ability of more distant firms to still participate in a large central market implies that "decentralisation strategies…[have] been encouraged by improvements in transportation logistics" (Scott, 1986, p.227). However, I would argue that it is likely that this is a localised deconcentration since the incentives for firms to congregate are not just a function of supply-side dynamics as a specialised cluster also draws buyers in from further afield (Marshall, 1890 [1948], p.273; Echenique, 2007, p.1785)[15].

[15] Research that attempted to put a cost on travel has suggested that although the monetary cost per kilometre travelled increased by 29% over the past ten years, time cost per kilometre fell by 31% because of increased speed (Echenique, 2007, p.1786). This would seem to fit with the idea advanced in Chapter 2 of rising travel distances for the purposes of consumption. That said, as Christaller and Lösch noted, there is an important qualification here: the strength of the draw of an agglomeration of specialised firms is connected to the type of product on offer; there is an enormous difference between the distances that shoppers would travel to compare basic goods and specialised ones (Marshall, 1890 [1948], p.273).

Technology: Technological change clearly has the potential to destabilise linkages and agglomerations because it enables more flexible connections to be established between agents, leading to "organisational shifts and changes in in-sourcing and out-sourcing behaviours with major impacts on regional economies" (Traxler and Luger, 2000, p.280). And as Audirac (2002, p.217) notes: "…[Electronic Data Interchange] and [Just-In-Time] processes have allowed firms to integrate production and distribution functions into centrally distributed systems, where proximity to industry and population is less important than easy access to transportation and ICT infrastructure." In other words, technology is enabling increasingly complex linkages to behave like stable, standardised ones.

We can also expect that spatial constraints on highly-skilled activities will loosen over time as a process becomes routinised or 'a previously remote area gains in human capital' (Scott and Pope, 2007, p.1368). However, ICT deployments in some companies may not be so much about increasing productivity *per se* as about deskilling or standardising previously difficult or expensive work so that it can be shifted out to lower-cost areas (Scott, 1986; Leamer and Storper, 2001; Wood, 2006; Scott and Pope, 2007). In the film industry, for instance, the switch to digital technologies has displaced jobs working with film, but it has also led to a rise in postproduction services and to an increased capacity for remote workers to collaborate effectively with the major studios in Hollywood (cf. Scott and Pope, 2007; Cole, 2008; SohoNet, 2008).

Over time, increasingly sophisticated technologies such as the 3-D printer may spawn entirely new types of customised production without the intensive involvement of labour (Economist, 2009a; Vance, 2010). However, mass customisation should not be confused with custom manufacture, and even such flexible systems as these are unlikely to be economical for the creation of truly bespoke outputs for some time. Moreover, skilled designers and equipment operators will still be required throughout the production of unstandardised outputs, suggesting that 'new work' will be created even as once-skilled tasks are subsumed by technology. In this I very much agree with Jacobs (1969, 1961 [2002]) on the role of innovation in cities creating new, more skilled employment in urban areas even as it undermines existing, lower-skilled jobs. Custom printed circuit manufacture in the form studied by Scott (1983b) almost certainly no longer exists in Los Angeles, but I would not in the least be surprised to find that some markedly more sophisticated form of customised design or production does.

Spatial Implications

The relationship between Hollywood and Vancouver, Canada—which is both a short (2 hours 43 minutes) flight from Los Angeles and in the same time-zone for coordination purposes—as a low-cost destination for film and television production is a useful illustration of how this relationship may operate in the real world. Air travel enables specialised staff and equipment to be easily moved on to location for short periods of time, but learning by on-site labour has also led to the outsourcing of activities that were previously 'locked in' to Hollywood (Scott and Pope, 2007, pp.1372,1377). Routine productions which require neither close supervision, nor particularly specialised staff, are the most amenable to off-shoring (2007, p.1367).

In contrast, large productions, and small one-off films may be quite resistant to off-shoring—some of this resistance may originate in the complexity of feature films, but it will also be driven by the overheads required to set up a production abroad (2007, pp.1367–1378). Outsourcing abroad is designed to minimise the accumulated expenses of caterers, drivers, costumers, grips, art directors and set construction workers by subcontracting out work whose relationship to the rest of the film process is relatively weak (2007, p.1366), but the success of the approach depends on how much the interactions can be standardised and managed from a distance which is why scale is also a factor.

These dynamics help us to understand why the off-shoring of made-for-television movies, which already accounted for 63% of productions in 1990, had risen to 81% by 1998 (2007, p.1370). However, this is not a one-time process: although Vancouver was the most convenient destination, it is now facing competition from Toronto—which has a 'vibrant, creative atmosphere and sturdy infrastructure of film-production'—as well as from production centres in Australia, New Zealand, and the Czech Republic (2007, p.1378).

In a very different way, it has long been thought that distance affects venture capitalist (VC) behaviour in two ways: in the diffusion of knowledge about opportunity, and in the transaction costs associated with monitoring and supervising the investment (Fritsch and Schilder, 2008, p.2115). Although Fritsch and Schilder makes some excellent points regarding the effects of space on the diffusion of information and ability for a VC to exert control over their investment, they largely overlook the idea that market 'size' is really an issue of accessibility. In other words, VCs are likely to choose the sites where they can reach the greatest number of firms with the least amount of effort. If the density of entrepreneurs is low—as it would be for a VC that specialises in a particular sub-category of firms—and the exact location of *successful* new firms is difficult to predict—as it would be in view of the number of businesses that fail—then it would be wise to choose a location with the lowest *average* travel cost. As a result, it is hardly surprising to find that VCs are predominantly urban creatures, and that the major conurbations or nearby suburbs are disproportionately represented in lists of large VC firms (Wikipedia, 2005a).

So while I am arguing that space is still important to many firms, in line with Goddard (1975, p.34) I wish to emphasise the idea that spatial association is no longer a *necessary* condition for functional linkages to exist between firms. Returning to the European animators, Cole

(2008) argues that they have managed to substitute a kind of 'proximity of standardisation' for the traditional geographical proximity of a Hollywood or an Ealing; and that this process is enabling them to coordinate even relatively costly, one-off productions remotely in a way that would have been inconceivable just a few years ago (2008, p.894). For Cole, this type of 'virtual clustering' is far more spatially diffuse than normally allowed for by firm location theory.

Summary

So in this section we have examined the role played by transactions—both internal and external—in determining the boundary of the firm. Following Scott's lead, we have considered how the demands of standardisation and coordination, as well as the scope for integration, impact the ability of the firm to expand output and manage risk. When internal transaction costs begin to eclipse the cost of organising transactions in the market, then the firm has an obvious incentive to source inputs on the open market. But clearly where this boundary arises depends on the firm's "internal information-processing capacities and effective managerial range" (Scott, 1986, p.220).

So we find that the boundaries of the firm are determined as much by its ability to manage information flows as by its ability to deliver a product or service cheaply! In fact, the two are inseparable, since better management may enable the firm to internalise and organise transactions that a less well-run firm cannot, or it may enable it to offload complex but peripheral tasks to a long-term partner and so be able to reap superior economies of scale. So the key concept for understanding the interaction between these three aspects of transaction costs has turned out to be the relative 'cost per unit of flow'. This can be framed in terms of the overheads of management and the cost of delivery: a transaction may be expensive to organise in absolute terms (*e.g.* depending on extensive negotiation, review, and collaboration) but yield millions of dollars' worth of 'flow' between firms, or it might be quite easy to organise and yet nonetheless have an intolerably high overhead for a small-volume transaction.

Naturally, the degree of integration between the functions of the firm varies from sector-to-sector as well as from firm-to-firm. And as Haig (1926b, pp.416–417) noted, in some industries the packet of functions involved in the delivery of a product or service is tightly-bound, while in others the functions can be readily broken up and allocated to optimal locations. In fact, if we put together the divisibility of the firm with the differing transactional requirements of divisions and sectors, then we will naturally tend to find higher order functions in the central district and lower-order functions being pushed out to cheaper sites (Haig, 1926b, p.414). It is in part for this reason that in Britain there is a near 'perfect' correlation between a firm's size and the likelihood that its headquarters are in London (Goddard, 1975, p.7).

Where the packet cannot be broken down into loosely coupled sub-components, then it has historically been entrenched in agglomerations. For instance, the packet of functions involved in the production of a film has historically been difficult to parse out into separate, and spatially-distant processes: each film is unique and entails unique challenges—such as the dynamics between cast, director, and other members of the team, as well the problems of set design and cinematography—as well as requiring close collaboration between producers and editors (Scott and Pope, 2007, p.1366). In this case, although the services may be provided by ancillary firms, the packet of functions remains tightly-bound, leaving little scope for more flexible spatial strategies in the absence of substantial changes to the costs of coordination.

Radical change to this aspect of transactions is, of course, exactly the promise of telecommunications and of specialised services such as SohoNet—it allows post-production houses in London to work with directors in Hollywood without the need for close physical proximity. In other words, technology is raising the threshold at which a transaction becomes so costly that more expensive forms of coordination are required. Taking the long view, Economist argues that companies should be moving away from 'command-and-control' towards 'co-ordinate and cultivate' structures (Economist, 2009b).

One example of this transformation is Cisco Systems: originally a network hardware manufacturer, today the company makes a great deal of its money from the services built around products that bear its logo, but which it may never even have handled on the journey from plant to customer (Economist, 2009b). In fact, the firm now even outsources a good deal of basic R&D as well (*ibid.*), and there is a sense in which the company is now more of a portfolio of firms producing products that use networks rather than a manufacturer of networking equipment. Effectively, Cisco is in the process of becoming a prototype *metanational* (Doz et al., 2001).

However, at times this complex reconfiguration may have the seemingly paradoxical effect of "strengthening the importance of central co-ordination and control functions for firms and, even, markets" (Sassen, 2004, p.196). In the case of information, "advances in telecoms and ICT can actually increase the need for institutions, people, and districts that can extract meaningful knowledge from the increasing glut of undifferentiated information…" (Townsend, 2001, p.42) However, the key point that we will take forward into Chapter 4 is that changes to the way transactions are managed and scale can set up feedback effects between a firm's divisions or collaborators. So the 'expansion of a branch or plant may also stimulate growth elsewhere in the organisation' (Goddard, 1975, p.13), and the addition of a new product category (*e.g.* HD video recorders by a manufacturer of networking gear) can also, to put in quasi-Keynesian terms, create management multipliers that 'leak' back into head office from peripheral production or design sites.

3.5 Conclusions: Telecommunications & Firm Spatial Strategy

We began this chapter with a review of Weber's original theory of firm location (1909 [1969]), and although it proved to be enmeshed in the movement and transformation of material inputs and outputs, it nonetheless proved to be remarkably useful for getting to grips with informational ones as well. In fact, by focussing on the firm in isolation while incorporating the findings from Chapter 2, we were able to investigate the implications of modern infrastructure for firms in much greater detail and saw that within-network distance was a more useful way to think of proximity than the more traditional 'featureless plain' that is usually taken as a starting point for spatial analysis.

We also saw how the concept of ubiquity could provide us with analytical purchase on the interrelated impact of ICT and information on firms. Getting to grips with this aspect of the contemporary corporation is vital since, as Economist (2010a) noted: "data are becoming the new raw material of business: an economic input on a par with capital and labour." Increasingly, even firms that are in the business of managing and moving physical products are finding themselves in the business of managing and synthesising data in order to improve their competitive position. Or as a vice-president of manufacturing operations, business operations, and customer experience at Dell Computer put it: "information flow is as critical as physical flow of product" (Economist Intelligence Unit, 2006, p.60).

But we also saw how some information-oriented goods and services defied easy categorisation as ubiquities, and continue to display features consistent with their being a localised input. This finding turns out to mesh rather well with the difference between search goods with readily identifiable and measurable characteristics, and experience goods without such readily-determined features. Using a typology of financial markets—transparent, translucent, and opaque—we were able to see how each had different spatial and risk characteristics, with very real implications for how firms could respond to and resolve these issues.

As well, we also began to unpack the notion of the atomic firm into a more flexible notion of interacting divisions organised around the principle of marginal cost. Grabher (2004, p.105) has argued that "the firm remains unproblematised as a unitary and coherent actor" and sits in a kind of 'privileged ontological and epistemological position', but I have tried to make clear that this is perhaps more a failure of neoclassical economic modelling than it is of economic thinking *per se* since Weber (1909 [1969]), Goddard (1975), and Scott (1983a,b, 1984, 1986), have all wrestled with ways that firms "may simultaneously alter their internal, external, and spatial organisation" (Bellet and L'Harmet, 1998, p.xviii).

The more subtle point is that while firms are in part a tool for the spatial division of labour, enabling entrepreneurs to exploit differences in labour and rent (Breheny, 1999, p.178), they are also a tool for the management of information. Thus the configuration of transactions—including the nature of their overheads and their impact on per-unit flows—highlights the fact that there is a real cost to searching for, and gathering information, and that these are not (and never will be) zero (Graham and Marvin, 1996, p.56). These findings help us to understand why even ostensibly footloose internet businesses are "rarely as flexible as imagined" (Breheny, 1999, p.25): they are constrained by the need to access skilled labour, the need to access clients, the need to coordinate activity both in the market and internally, and the need to keep track of what all of this means for the bottom line. In short, firm structure lies at the intersection of risk, coordination, and transactions.

If we think in terms of stability, standardisation, and flows in different sectors then we can elaborate upon the distinction established in Table 3.2 (page 93) using the schema set out in Figure 3.7. Some firms, those in manufacturing and call centres for instance, operate in markets where stability and standardisation is the best route to profits through economies of scale. In those sectors, information has the characteristic of a ubiquity thanks to the role of telecommunications in rendering the market transparent, and so there is little purpose to remaining in high-cost centres such as large urban areas unless a specific labour dependency arises. In effect, these firms can exploit the advantages of logistics and ICT to become hyper-mobile. That said, we must also note that the 'scattering' made possibly by ubiquitous information may also "intensify this need [for copresence] among those whose job it is to coordinate dispersed activities and the plethora of information pouring in from diverse settings" (Boden and Molotch, 2004, p.104).

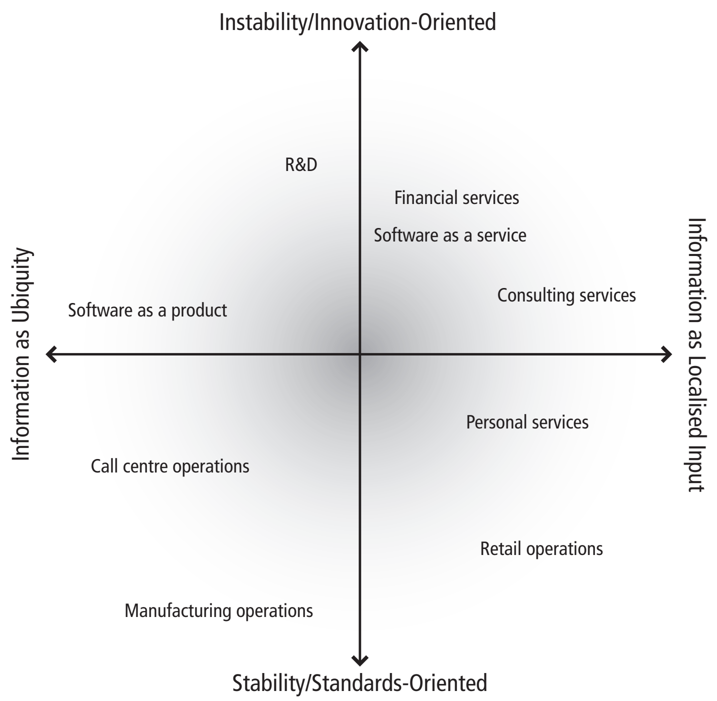


Figure 3.7: Proposed Interaction Between Transactional Patterns & Informational Orientation

Meanwhile, others firms thrive in situations of uncertainty where information is deeply local: at the end of the day, personal services are necessarily about the individual buyer, while consultancies grapple with the particularities of each client's business, product lines, and culture(s) in order to deliver value for money. Here, firms will benefit from being able to access mobility and communications infrastructure in order to be 'on site' (whether physically or virtually) quickly and cheaply. However, while both types of companies use localised information as an input, a key distinction between personal services and consulting is that the former can exploit both the 'law of large numbers' (*i. e.* using data processing power to offer customised, but *also* standardised recommendations to consumers) and the underlying stability of the market (*i. e.* the sale of books is ultimately a standardised process) to bring technology to bear on their operations. This process weakens the place-binding of information in a way that creates greater competition over larger distances.

In contrast, consultants continue to sell individually tailored services to clients, and so within a transaction model we can think of this sector as having particularly high overheads and low levels of standardisation: in short, it is a labour-intensive product with little likelihood of becoming a capital- and automation-intensive business in the near future. The nature of sectors such as consulting also means that the overheads involved in managing and coordinating output are almost certain to scale at least linearly with the volume of output itself: the value of each transaction is high, and the cost of coordination is also high. This imposes high transaction costs on the firm, creating further incentives for such firms to concentrate in high-accessibility areas.

An interesting contrast to this is the firm in the software-as-a-product sector: they operate in a world of pure ubiquity since informational inputs in the form of each programmer's code, and informational outputs in the form of a working application are both effectively placeless. Consequently, they can be said to have just one dependency—labour—for which they should be willing to relocate almost anywhere. As we will see in Chapters 4 and 5 the picture is a little more complicated than this, but I am still inclined to agree with Breheny's assertion that, while we can expect that cities will remain important employment nodes, this does not in the least imply a re-concentration of employment there (Breheny, 1999, pp.24–25).

4
Agglomerations and Clusters

4.1 Introduction

We have examined in some depth the spatial aspects of infrastructure and markets, as well as the impetus that they may provide for integration or agglomeration, but it is helpful to take a step back and consider this process in a more general way. We have only thus far considered factors that would drive a firm in isolation to seek proximity to suppliers and competitors, and we have not yet considered how this might create feedback effects that influence the choices of other firms. For this, it will be helpful to draw upon Marshall, whose *Book IV*, *Chapter X* in *Principles of Economics* (1890 [1948]) focusses on the positive externalities that arise when many firms concentrate production at a single point in space. There is good reason for this since, as Traxler and Luger (2000, p.287) rather dramatically note, "cities and agglomerations only exist and will only continue to exist if spatial clustering of economic activity leads to economic advantages."

The focus of this chapter is therefore very much in keeping with the current "emphasis on positive externalities as a major source of economic development" (Scott and Storper, 2003, p.580). However, what makes this chapter challenging is that there are a host of overlapping and conflicting definitions in widespread use to describe the nature of these externalities: the literature contains references to agglomerations, 'growth poles', 'neo-Marshallian districts', and clusters, to name just some of the more common ones. Moreover, for some authors there seems to be little or no difference between, for example, an agglomeration and a cluster, while for others these terms refer to fundamentally different configurations that can occur both independently *and* simultaneously. Consequently, one objective for this chapter is to establish a clear theoretical framework to use as a basis for exploring the knowledge-based economy in Chapter 5.

Whether we work with agglomerations, clusters, or districts, these groupings are all affected by two dimensions of economic activity: scale and life-cycle. Economies of scale may be internal or external to the firm, and in the latter case they may characterise a single sector—a localisation economy—or a diverse set of sectors—an urbanisation economy. Similarly, the life-cycles of products, firms, and sectors are thought to affect the extent of scale economies and the benefits of agglomeration, but note that these need not coincide in any definite way. For instance, a firm may be well-established within a sector that is still in the early stages of its development; however, as I hope to show, there are still predictable correlations that should enable us to make some informed projections about how firms are likely to respond spatially and organisationally to the challenges and opportunities of agglomeration and clustering.

4.2 Lifecycle & Scale

The idea that products, companies, and sectors have naturally occurring life-cycles—that they are born, mature, age, and ultimately die—suggests a natural order to business activity, enabling firms to determine their (or their product's) stage of development so as to decide on the best growth or survival strategy. However, substituting a linear biological metaphor for a complex socio-technical process is a risky process: a firm could easily move straight from birth to death (many do), a product might mature but never decline thanks to customer demand and a lack of effective competition. So let us begin by noting that this concept should be handled with some care because the choices of firms may dramatically alter the long-run outcomes and 'life-cycle' of a product (Dhalla and Yuspeh, 1976).

A particularly vivid illustration of this point can be found in Gladwell (2000, pp.3–5), where he attributes the resurgence of the Hush Puppies brand—a shoe company that was by most measures at death's door—to the trend-setting influence of a small group of particularly well-connected and stylish young people who made it cool again. The revival of demand for Hush Puppies' products does not neatly fit into any deterministic model: we could argue that the brand had been 'rejuvenated', but this overlooks the fact that its 'resurrection' was driven by arbitrary shifts in demand, not by some natural selection process or any basic product innovation. And in the broader context, we should note too that this example is also abundant demonstration that there is no necessary connection between the life-cycle of product, firm, or industry (Menzel and Fornahl, 2010, p.2).

With these important qualifications in mind, we can still draw upon our understanding of transactions and risk from Chapter 3 to see how the development of new technologies and markets can impact the distribution of firms. And reinforcing these evolutionary dynamics are the effects of three types of economy of scale: economies internal to the firm itself; localisation economies resulting from the concentration of a single sector or set of interdependent sectors at a single location; and urbanisation economies accruing to diverse industries at a single location (Hackler, 2000, p.201). These scale effects create feedback dynamics that compensate firms for the relatively high costs of choosing congested, often urban locations over cheaper, more remote ones.

'New Work' and Product Lifecycles

Historically, the early stages of a product's development have tended to involve labour-intensive processes such as research, design, and prototype manufacture. Given the relative flexibility of labour (see page 104 for a fuller discussion), its abundance in cities, and a long-standing association between urban areas, universities, and research centres, it is hardly surprising that there seems to be a correlation between innovation and urban environments (cf. Dawkins, 2003, p.141).

Jacobs (1969, 1984) distinguished between 'new work', which she argued was intimately connected to the diversity of economic activity in the city, and routine work that could be performed more efficiently in suburban and rural areas where the costs of land and labour are significantly lower. Standardisation would lead firms to 'expel' routine work from high-cost locations and internalise it at lower-cost sites where the advantages of volume production are at a maximum (Goddard, 1975, p.50). Support for the 'specialisation-expulsion hypothesis' can be found in a range of research: for example, Gaschet (2002, pp.74–78) was able to document that 'low-order' (*i.e.* routine) functions were expelled most strongly from those French cities with the greatest concentration of high-order functions in growing sectors.

So "there is an ongoing transformation of complex and unfamiliar coordination tasks into routine activities that can be successfully accomplished at remote but cheaper locations" (Storper and Venables, 2004, p.367). If this were a one-way process, then perhaps product life-cycle theory would have greater relevance to urban planners, but as Storper and Venables also noted: innovation can actually cause new 'coordination problems' to arise, bringing work back to the skilled urban workers. In effect, technical advances need not always lead to increasing specialisation or routinisation, but may stimulate a 'resynthesis' in which previously separate operations are merged into a single, new process (Scott, 1986, p.218).

As a result of these issues, simpler treatments of the product life-cycle have some important weaknesses (see: M. Taylor 1986 in Dawkins, 2003, p.142). First, they are at odds with models of incremental innovation as embodied in, for instance, Toyota's 'Kaizen' philosophy. Second, they ignore the capacity for product differentiation to protect and perpetuate markets—this effect is, for instance, particularly pronounced in the pharmaceutical market where the availability of generic substitutes for brand name drugs seems to have only a modest impact on consumer preference. Third, they assume that labour or land costs are the primary consideration for firms.

These are rather abundant conceptual shortcomings, but the concept of the 'life-cycle' remains a useful shorthand for discussing the balance between routine and non-routine interactions within a firm or a market. And if we narrow the focus a bit, to the pattern of transactions, then we *can* draw out some useful implications: in sectors where new products and radical innovation are a way of life, then routinisation is difficult to establish and so the advantages of access to partners and competitors may trump the long-term cost advantages of more remote locations; but where the innovation process is less 'traumatic' then more flexible strategies become viable since the process itself is more predictable.

We can put this in more concrete terms by comparing high-tech manufacturers in Silicon Valley with car manufacturers in Detroit. Electronics firms in Silicon Valley compete in a sector where entirely new product classes are created on a regular basis and where new information must be constantly acquired, and existing knowledge updated, in order to remain competitive. In fact, perhaps the only real certainty in Silicon Valley is that you will need to engineer something largely from scratch—an iPod or an iPad, for instance—using new chips, display technologies, and form factors, every few months, and that your market-leading product from last year may well already be obsolete. In contrast, car manufacturers compete in a market where innovation is, for the most part, predictable and incremental: new features (safety-related or otherwise) may be added, but the underlying product remains largely unchanged. This dynamic means that even labour-intensive and innovation-oriented processes such as design are actually rather predictable: the skill sets are well-understood, and the interactions between teams within the firm can be 'programmed' and managed accordingly.

Internal Economies

We have already seen in Chapter 3 that, broadly speaking, the 'units' of a firm can be internalised or externalised according to the dictates of marginal efficiency. At the very least, negotiating this boundary requires a management function that is not part of the production process *per se* but is integral to the successful coordination of intra- and inter-firm flows of material and information. More generically, Scott (1986, p.225) divided the modern corporation into three functional groups: 1) management and control; 2) skilled tasks requiring particular qualifications; and 3) deskilled processes. So even the most basic model of a straightforward manufacturing firm could therefore usefully include a management entity that coordinates resources, a marketing unit that promotes the firm's output, and a design unit that produces the firm's next generation of products.

Figure 4.1 illustrates the implications that this breakdown of the firm into sub-units has for the dominant conception of corporations employed in some economic models. On the one side are controllable and uncontrollable flows of *information* to the management unit of the firm, and on the other side are coordinated flows of *material*. In this figure, the administrative and productive units actually have more external dependencies and interactions than they do internal ones, though realistically the scale and volume of external interactions will vary with the firm and unit under consideration.

Consider also that for each unit the linkages may scale very differently as the firm adjusts its output towards some hypothetical optimum. This is, in fact, the central insight of *The Structure of Competitive Industry*

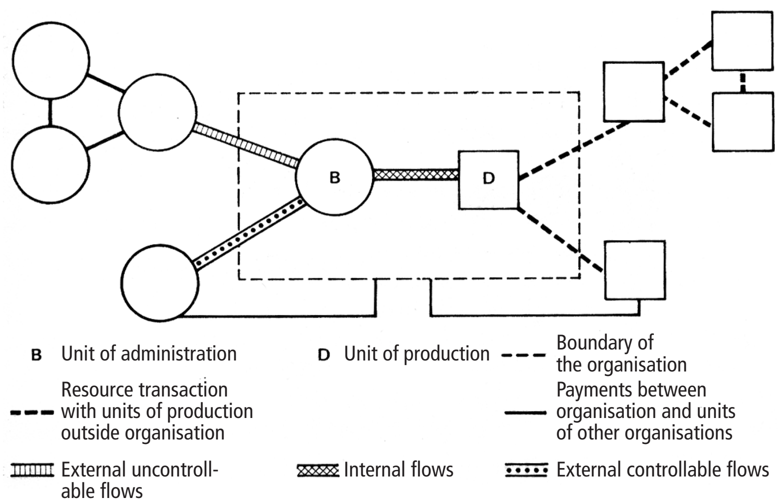


Figure 4.1: Flows of information and external economies (after Thorngren; Goddard, 1975, p.12; reproduced with permission of Oxford University Press)

(Robinson, 1931 [1943]): it suggests that entrepreneurs employ both organisational and spatial processes to enable each division or factor within the firm to achieve its *own* optimum scale (1931 [1943], p.108). The scale of the firm is therefore neither purely the product of a production technology, nor of a market, but is actually bound up in the transactional and informational dependency structures of the firm itself.

Independent Scaling of Divisions: If each division has a role to play in determining the firm's overall size, then instead of a single point of optimal efficiency, the interactions between units create an envelope within which the firm can profitably operate using a variety of configurations. The range of possible configurations means that, for Robinson, the classical micro-economic equilibrium is actually highly unstable since the optimal scale for production may not coincide with the ideal size of the management and marketing functions. Robinson puts it in terms of a multi-way tug of war in which it is impossible to tell whether no one is pulling at all, or if everyone is pulling in a different direction but the forces are temporarily cancelling each other out (Robinson, 1931 [1943], p.17).

By implication, management and marketing functions may not scale linearly, and sometimes may not scale at all, with the overall level of output of a firm (Robinson, 1931 [1943], pp.40,65). Thus a key challenge for the entrepreneur is how to reconcile, say, a smaller output optimum with a larger marketing optimum (1931 [1943], p.117). For instance, although the market for rail infrastructure is enormous in terms of its output, it may require relatively little in the way of marketing because there are few customers for its wares (1931 [1943], p.70). In contrast, the market for telecommunications or electronics may need management or marketing to scale up far beyond the number of people involved in design and production—we have only to look at the amount of money spent by Microsoft, Apple, and their various competitors and collaborators on advertising to consumers and other corporations.

In fact, if a marketing department succeeds in expanding the market for a given product, then it will have lowered the 'per unit of production' overhead (Robinson, 1931 [1943], p.40) and enabled the firm to expand beyond the original manufacturing optimum (1931 [1943], p.82). In other words, the functional specialisation of groups within large firms creates new economies of scale; and yet, the scaling up of marketing and management overheads may simultaneously also create a minimum size below which the firm can no longer profitably operate.

In some cases, the solution to this challenge may be to outsource one or more 'internally inefficient' functions so as to take advantage of economies of scale or special skills available nearby. At other times, because of risk and coordination issues, it may be more sensible to internalise these roles even if it is not, strictly speaking, efficient to do so. So in the context of transactional and informational flows, a range of spatial and organisational responses might follow: we could have centralised management with dispersed production, or its opposite, and we can have integrated production, management, and sales, or management can hand-off some tasks to specialised service firms to extract additional economies (Robinson, 1931 [1943], p.117).

Multiple Local Optima: However, note too that the notion of independent variation in the scale of each division creates the possibility that multiple locally-efficient and profitable optima exist for a firm. The scaling up of marketing functions may markedly increase demand for a product, enabling the firm to bring on-stream a new technology and, subsequently, a substantially higher level of output. This transition does not mean that the previous output level was necessarily inefficient: the investments in new plant and new marketing outputs might offset any gains in scale if the older plant had lower costs and a simpler operation that made for more modest management needs. This feature of Robinson's model helps to shed light on the allowance in Scott's approach for multiple output technologies to coexist comfortably within a single sector (1983b, p.349).

So instead of an envelope, it is perhaps better to envision a complex landscape of peaks and valleys. The peaks represent local optima where particularly efficient and generally stable configurations of marketing, management, and production arise. In valleys, the configuration of units or divisions is unbalanced and unprofitable, and costs are difficult to recoup. A growing firm must somehow negotiate the gaps between optima; if the gaps are small then the firm may be able to make the leap using external financing or internal resources, but where this gap is particularly large we can expect growth to occur through horizontal integration instead (Robinson, 1931 [1943], pp.123–124). To put it in more concrete terms: a firm may wish to expand production using new technology at a cheaper, remote location but be unable to do so because of the overheads involved in setting up an entirely new facility (Scott and Pope, 2007, p.1367).

The Risk of Failure: Moreover, as a firm expands, the effect of a single mistake in planning or execution may become more severe than they would be for a smaller one (Robinson, 1931 [1943], p.66). And this brings us to the second of Robinson's insights: the problem of coordination. Since perfect coordination and knowledge are impossible there is an implicit upper bound to the size of the firm in any industry because there comes a point where the risks created from further growth overwhelm the economies of scale resulting from specialisation (Robinson, 1931 [1943], p.45)[1]. Large firms may eventually become so complex that no one person truly has a good sense of its activities:

> …More and more leverage in the system, the entire system is about to crumble any moment…the only potential survivor the fabulous Fab…standing in the middle of all these complex, highly levered, exotic trades he created without necessarily understanding all the implications of those monstruosities [sic] !!!
>
> *Email of Tuesday, 23 January 2007 from Fabrice 'Fab' Tourre, trader at Goldman Sachs, to his girlfriend, Marine Serres; Sibun, 2010*

Like Coase (see page 98), Robinson predicted that smaller firms or divisions would be found in industries where there are substantial risks of failure and where frequent decisions and rapid coordination are required. For instance, even though the scale of modern financial institutions might seem to militate against such a conclusion, the investment banking and hedging units of commercial banks are in fact much smaller than their consumer-oriented divisions. And even within small financial institutions we tend to find specialist teams working in physical and virtual proximity to one another. However, there is little to suggest that the control processes required to manage the risks taken by these teams will be radically improved by anything short of a revolution in how they are run[2].

Robinson (1931 [1943], p.50) also noted that the strength of small firms is greatest where 'fashion rules'—used here in the sense of frequent changes in preferences and output—and the contemporary fashion industry is a particularly good example of this. Fashion designers may have a general 'look' for which they are known, but each season's collection constitutes a fairly radical overhaul of production. Moreover, these cycles are very short and so the risk of complete failure (or runaway success) recurs constantly, creating an underlying and persistent uncertainty that is thoroughly incompatible with scale. This is why for many labels the team *is* the firm. Larger firms in the fashion industry tend to be built around the advantages of distribution, not design, and frequently operate a stable of competing brands that each combine standardised outputs with limited edition collections.

An additional configuration is suggested by Grabher (2001), who notes that Soho's advertising industry seems to actively court chaos with ongoing mergers, de-mergers, and shifts of role and responsibility. The 'heterarchy' embodied in both the global agencies and amongst the smaller independents who take on different tasks in different projects, has a 'very high tolerance for internal diversity' (2001, p.353). This complex ecology promotes a situation in which work and staff are

[1] An interesting example of how scale can work against large firms is the disruption to world markets attributed to Société Générale's secret unwinding of positions taken by its 'rogue trader' Jerome Kerivel: some analysts allege that the bank's rapid exit caused an 8% overall decline in European markets (Chrisafis et al., 2008). Regardless of whether these trades actually drove the market down, it is clear that the sheer scale of the anomalous positions forced SocGen into a 'fire sale' of assets and that these losses would have been lower had the transactions been smaller and the firm been able to wait to close out Kerivel's positions.

[2] Consequently, Robinson's model lends support to the idea that the breaking up of banks that are 'too big to fail' may well be an appropriate regulatory response.

endlessly recombined in new configurations so that boundaries are 'perforated' but a common culture of sorts is nonetheless created. For Grabher, this approach is not so much about finding a 'solution' to an immediate problem as it is about becoming better at searching for solutions to a client's problems (*ibid.*).

Localisation Economies

Looking now beyond the individual firm, localisation economies emerge when firms are able to pool demand so that a specialised product can be sold either to more than one company or to one particularly large company (Marshall, 1890 [1948], p.275). Localisation economies are typically understood to arise around the activity of a single sector, so the congregation of car manufacturers in Detroit is an obvious example, as is the concentration of finance-work in the City of London and on Wall Street. Derived demand for specialised products and services geared to the dominant sector then spawns a host of companies whose existence is predicated on supplying the key firm or firms.

The idea that some sectors and firms are essential to regional economies and growth is often embodied in cities' attempts to secure the offices of what NESTA calls 'anchor firms' (Athey et al., 2007, p.19). The principle is that a key sector can be used to stimulate employment and to 'pin down' a host of related activities connected to the supply of services and products to the core sector. These firms may also create new employment through spin-off processes: the case of Silicon Valley's 'Fairchildren' illustrates the way that in some circumstances even a single firm, acting as a kind of 'focal point' for an emerging localisation economy, can spawn a host of enterprises that share both a similar 'process DNA' and, frequently, social connections as well (Menzel and Fornahl, 2010, p.6).

Cook et al. (2007, p.1334) use survey data from the City of London to argue that vertical linkages between the bankers and their 'suppliers'—who in this case are found in the legal and accountancy sectors—are vital to the success of the area as a whole. Similarly, research into the biotech sector indicates that the presence of larger firms has encouraged new start-ups to locate nearby, and that their pursuit of innovation positively impacts local businesses through the contracting out of various functions (Athey et al., 2007, p.47). This same basic logic underpins the government-mandated 'Out of London' strategy for the BBC and its relocation of production, post-production, and associated processes to second- and third-tier British centres such as Belfast, Cardiff, Glasgow and Manchester (BBC, 2005a; Conian, 2008).

However, these relocation policies rest on two important assumptions: that localisation economies are a spur to regional development, employment, and local innovation, and that this impetus is sustainable in the long run. Clearly, in many cases the emergence of a localisation economy can produce initial innovation through the scaling up of production: specialist parts suppliers and services firms develop to serve the burgeoning auto industry, for instance. But as early as Marshall (1890

[1948], p.273), important questions were raised about the ability of localisation economies to support long-term innovation. The risks for regional economies dominated by a single industry include technological lock-in and a kind of group-think that encourages firms to dismiss 'paradigm changes' originating outside of the area (Martin and Sunley, 2003, pp.22–23).

Checkland (1976) coined a rather memorable term—the Upas tree effect—to describe the way that the long shadow of a singularly dominant sector could stifle the emergence of new business. Named for the poisonous *Antiaris toxicaria* that was purported to destroy other growth for 15 miles (1976, p.iv), the effect appears when an established firm or sector starves competitors, spin-offs, or start-ups for resources. In some cases this process may be deliberate: a large firm might impose exclusive contracts on suppliers or apply pressure on local government for preferential treatment or regulation. But it could also be entirely inadvertent: a 'not invented here' syndrome that blinds firms to emerging threats or opportunities. In either case, since all economic activity is geared to the core firm or firms, any negative repercussions (*e.g.* negative long-term health outcomes or skills made redundant through technology change) will have a disproportionate impact on the region's ability to recover from the collapse of the dominant industry.

Glasgow is a particularly good example of this process since early successes in heavy engineering, and in shipbuilding in particular, undermined the growth of nascent 'modern' industries such as automobile and aircraft manufacturing (Checkland, 1976, p.48). In time, an inability to diversify meant that the economy became utterly dependent on just a few employers: by 1968 the 100 largest enterprises accounted for fully 70% of regional employment (1976, p.64). With such a narrow focus, it is hardly surprising that local businesses failed almost completely to anticipate the impact that air travel would have on demand for passenger ships (1976, p.48). Yet even had they anticipated this shift, they faced two additional challenges: first, they would have had to develop a 'managerial psychology' of consumer manufacturing completely at odds with their existing knowledge of heavy industry (1976, p.11); and second, labour would have had to be willing to migrate to work with only the most efficient firms, instead of demanding only those firms' rates of pay (1976, p.50).

Additional evidence of the Upas Tree effect comes from places as far removed as Rochester, New York (Jacobs, 1969, p.96) and the East Midlands (cf. Beatty et al., 2002). However, the most glaring recent example is the way that Detroit's historical success in automobile production seems to have meant that the Big Three producers—Chrysler, Ford, and General Motors—were largely 'asleep at the wheel' when Japanese manufacturers began to devise entirely new methods of managing inventory and production (cf. Halberstam, 1987). Of course, it was not always like this: at its inception, industrial activity in Detroit was quite well-balanced (Hall, 1998, p.488) and the early auto industry displayed many of the dynamic qualities that—as we will see later—are associated with the emergence and growth of innovative clusters (Menzel and Fornahl, 2010, p.22). But the consequence of the motor industry's success, combined with the massive economies of scale in production, meant that, like Glasgow, Detroit would have no other industries on which to fall back when the vehicle producers, with their 'big firm' culture, got into trouble. Today, the wider metro area's unemployment rate stands at 15.4% (Bureau of Labour Statistics, 2010), but within Detroit proper the combination of unemployed, underemployed, and 'no longer even looking' is thought to account for fully 50% of the working age population (Wilkinson, 2009).

Urbanisation Economies

As the name suggests, urbanisation economies are associated primarily with large cities, but in contrast to Detroit's industrial monoculture, they are associated with the interaction of many sectors simultaneously. In part, these economies are tied to efficiencies gleaned from the sharing of capital-intensive infrastructure between many unrelated firms (Scott and Storper, 2003, p.582). But they are also tied to the sharing of input and output structures, so here a single firm supplies its goods or expertise to a diverse range of industries and entirely new needs can emerge (Marshall, 1890 [1948], p.271). The combination of these factors means that particularly large, diverse cities such as New York are "a good place for firms that rely on external economies" (Currid, 2007, p.47).

Using the seemingly trivial example of brassière manufacturing in New York, Jacobs (1969, p.56) argues quite cogently that urbanisation economies—incorporating both planned and fortuitous interactions between economic agents—are a primary source of innovation and long-term economic resilience. We can see in the rise of the 'new media' industry in San Francisco the binding together of the existing creative and high-technology sectors in the region, and this mingling has spawned a variety of innovative products and services ranging from many web design firms to the more recent rise of 'Web 2.0' companies (cf. Movers 2. 0, 2008). In effect, the existing 'flavours' of economic activity in Silicon Valley—and Silicon Alley as well, for that matter—were combined in novel ways by entrepreneurs who had both the industry expertise and market exposure to identify and exploit an emerging opportunity at the boundary of two or more existing sectors (cf. Zook, 2004). This, I believe, helps to explain an observation by Menzel and Fornahl (2010, p.5) that "locations with older but related industries have a higher likelihood of forming a cluster."

Jacobs seems to have envisioned recombination within urbanisation economies as a largely unpredictable process. And in *The Warhol Economy*, Currid (2007, pp.66–67) recounts the way in which an unplanned interaction on a New York sidewalk led to her being able to interview the fashion designer Marc Jacobs for her research after months of trying to obtain a chat through more formal routes. Currid (2007, p.9) suggests that the walkability of cities such as New York and London encourages these fortuitous encounters and is a key driver of their commercial success but, more generically, the easy flow of information from person-to-person will make firms aware of opportunities or threats well before they become public knowledge. We will return to this issue in more detail later in this chapter.

Labour Economies

POOLING: Labour pooling is typically handled separately from the more market-focussed externalities of localisation and urbanisation economies. On one level pooling is simply an economy of scale in labour markets where we deal with "specialised skills rather than specialised products" (Scott and Storper, 2003, p.583; Storper and Venables, 2002, p.7). However, pooling is also a response to risk: labour with substantial investments in specialist skills is drawn to areas where it is in demand because the 'cost' of unemployment is relatively greater than it is for less skilled workers (Marshall, 1890 [1948], p.271; Storper and Venables, 2004, p.352)[3].

Financiers who were asked to rank the benefits of a City of London location chose 'the ability to tap a strong labour market' as the second most important factor in their decision (Cook et al., 2007, p.1332; Athey et al., 2007, p.28). So the scale of London's specialised markets is a key competitive asset since firms find depth of expertise, while employees find that it 'provides a better chance of continuity of employment and supports specialist skills training' (Cook et al., 2004, p.14). Moreover, the decline of the 'job for life' and the rise in short-term and project-based contracts in high-skill fields means that the search cost of new employment recurs with higher frequency than before; in short, "successful labour markets in innovation-rich sectors become magnets for talent" (Athey et al., 2007, p.28).

Short-term employment is particularly common in the cultural industries—film, advertising, and design, for instance—where freelancing and project partnerships abound. While the rewards for a successful creative collaboration can be enormous, there is also a high risk of failure if the 'right' staff are not selected. The existence of a deep labour pool in a very localised market creates the ability for employers to identify promising collaborators through a mix of informal and formal channels (Cook et al., 2004, p.16), and this issue will be discussed in more detail on page 150. For now, note only that the risks of failure also mean that a great deal of work must be put into the search phase of a project, and so looking for staff or for work may be as costly and time-consuming as the work itself. Consequently, any 'shortcuts' to the qualification of partners, employers, and employees will provide a valuable competitive advantage.

I also argued in the preceding chapter that linkages between firms can take the form of informational exchange[4]; however, labour market churn is clearly a second conduit for the circulation of information since "mobile workers are carriers of knowledge on the local labour market" (Keeble and Nachum, 2002, p.81). There is, however, no reason why

[3] In this analysis we are not particularly interested in the cultural dimensions of entrepreneurship, or the mechanics of hiring and firing, though as we noted earlier these factors are clearly relevant. Cultural and legal practices can be understood primarily as a 'drag' on markets; depending on one's political or economic viewpoint this may or may not be a good thing, but clearly such policies may have an important effect on the process that we are considering here.

[4] Meier (1962, p.128) suggests that "the flow of information in a social unit has many of the same properties as the flow of economic values", and that the latter can be considered a kind of 'special case' of information exchange.

we should confine ourselves to the local market, and Cole (2008, p.898) suggests that "economic geographers have begun to pay more attention to long-distance labour migration that ties together labour markets and diffusing information." Regardless of whether the circulation is voluntary (entrepreneurs identifying a new opportunity) or involuntary (employees being laid off during a recession or bankruptcy), departing workers carry with them a wealth of ostensibly confidential information. America's Silicon Valley offers abundant examples of employees leaving a parent firm and setting up shop just down the road to offer competing or complementary products and services. Figure 4.2 outlines the relationship between the dysfunctional Shockley and the host of 'Fairchildren' (and see Hall, 1998, pp.435–440).

Figure 4.2: Fairchild Semiconductor and its Spin-Offs (Hamilton and Himelstein, 1997)

The rapid movement of employees between firms ensures that innovations are likely to be quickly copied by competitors, or even combined with other processes to produce ongoing innovation (Marshall, 1890 [1948], p.271). Since highly-skilled employees will tend to experience the greatest benefits from frequent changes of employer, we would expect to find particularly active churn in the most competitive labour markets. This certainly seems to be the case in London, where SMEs tend to hire locally (70% of recruits) and from large firms (42% of recruits), enabling sensitive knowledge to spread quickly (Keeble and Nachum, 2002, p.81). Cook et al. (2007, p.1333) put average annual turnover in staff within the City of London's at 25%, and rate it an important channel for the circulation of best practice.

MOBILITY: Increasingly, the mobility of individuals and households seems to be impacting their spatial preferences and, consequently, those of firms with specific staffing requirements. Mugerauer (2000, pp.222–225) suggests that three basic factors drive the locational choices of households: utility, amenity, and sociability. The utilitarian aspects of location include the basic costs of housing, space, and access to services and infrastructure. Amenity incorporates 'non-social' externalities such as a prestigious location, and access to cultural goods. The social aspects are primarily understood as the likelihood of finding a fulfilling *non*-work life in a given residential area. Crucially, Mugerauer (2000, p.225) finds that, today, many households assume that their utilitarian concerns can be met from nearly any geographic location and so focus on amenity and sociability (cf. Leland, 2007).

In *The Economics of Location*, Lösch (1954 [1973], p.16) allowed that an entrepreneur might well be guided by amenity in the selection of a site for his or her new firm, and he went on to suggest that this behaviour was entirely reasonable so long as the new site fell within the 'spatial envelope' of profitability (1954 [1973], p.247). More recently, Beyers (2000) and others (cf. Nachum, 1999) have also argued that the spatial decisions of small consultancies may be affected as much by the personal preferences of their founders as by the business logic of market access. So whereas, historically, basic transportation or communication needs might have constrained such choices, today this pattern is much more strongly shaped by amenity and its evolution over time—the life-cycle of the entrepreneur's household itself, if you will.

Employees in particularly specialised sectors have often preferred to live in cities 'for reasons of consumption, taste, and social relationships' (Beyers, 2000, p.162). And for the highly-skilled young—those most in search of opportunity and sociability—the city is, again, a preferred location (Glaeser, 2006, pp.15–16). This is why it is hardly surprising that "factors such as [amenity] and cultural diversity help underpin urban growth and innovation" (Athey et al., 2007, p.21)[5]. Reduced to the bare essentials, this is largely the argument of Florida (2002a) and his 'rise of the creative class' thesis.

However, as these workers age and form families with a preference for space, security, and access to schooling, then more ambiguous or

[5] The deeper demand for skills in major cities actually benefits all workers, including less-skilled migrants: data from France suggests that a one-point increase in the number of college graduates in a city translates into an overall wage increase for *all* workers of between one-half and one-percent (Charlot and Duranton, 2004, p.14).

complex trends seem likely to emerge. The ability to 'telecommute' (of which more in Chapter 5), together with the mobility options enabled by car, train, and plane, creates a new kind of 'accessible rural idyll' in which entrepreneurs and specialised consultancies—such as Comedia/Charles Landry, SQW, and GeoFutures to name a few in the planning field—can base themselves in non-urban but amenity-rich environments. So depending on the degree of dependency, companies may be 'pressured to follow the labour market' into the suburbs' (Breheny, 1999, p.19), and it is clear that edge-city development stems at least in part from "from executive and worker preferences for suburban living" (Leigh, 2000, p.329); or as Breheny (1999, p.9) puts it: "the residential preferences of entrepreneurs and professionals for the 'tamed rurality' of towns and villages."

Transportation & Technology

Transportation: The scope of economies of scale and employment will obviously be augmented by anything that increases the overall accessibility of a location. So a reduction in travel costs sets up a situation in which, barring the negative effects of long commutes, employees can live ever-further from their place of employment (Paumgarten, 2007; U. S. Census Bureau, 2005). This, in turn, gives businesses the ability either to draw on wider and deeper labour markets without needing to relocate, or to move their facilities to previously impractical locations outside the urban core where they benefit from both lower costs and improved access, especially if their staff are drawn from suburbanised locations (Gillespie and Green, 1987, p.401).

In some cases, such as computer services (which now extends to homes and home offices), changing locational behaviours may be driven by changes in the sector's client base (Coffey and Shearmur, 2002, p.376). But businesses with larger and more complicated staffing needs cannot move to truly remote sites as most people seem unwilling to suffer regular commutes of much more than an hour each way. So the suburbanisation of the workforce was a prerequisite for business outmigration to edge cities, and the link between the amenity value of suburbs and the movement of educated households to those areas is clearly an underlying factor in this process (Gaschet, 2002, p.66; Leigh, 2000, p.329).

The trend towards 'employment sprawl', especially when combined with changes in the ICT environment, clearly complicates the idea of a 'local' market and the range over which localisation and urbanisation economies can successfully operate. Robinson (1931 [1943], p.148) distinguished between scale economies that are 'mobile' (their benefits can be accessed from other locations) and those that are 'fixed' (the firm is spatially-constrained). In other words, some economies of scale behave like ubiquities, while others remain localised, but better transport means that these distinctions may become less relevant as all areas become more accessible.

For instance, Beyers (2000) explores niche markets in America where the service is so specialised that demand is actually quite diffuse, and suggests that it is only the improvement in transportation that enables this demand to become a proper market. He also finds, however, that although these providers are able to locate with greater freedom, this shouldn't be confused with true economic decentralisation since many of these firms depend on clients in centralised, CBD-type locations (Beyers, 2000, p.162). Examining this dynamic from a different standpoint, Keeble and Nachum (2002, pp.78–79) found that the emergence of SMEs in high-amenity but non-urban locations seemed to have been driven by an outmigration of entrepreneurs from London.

For British firms on this model (such as the ones named above), locations within the Greater South East of England (GSE) generally offer access to both Central London and to major airports, such as Gatwick and Heathrow, all from a semi-rural environment that punches well above its weight in terms of cultural offerings. In part, this is undoubtedly thanks to the presence of university towns such as Oxford and Cambridge (as is also the case with, for instance, Princeton in America), but it also owes a great deal to the fact that, in some cases, the entrepreneurs are only really 'resident' in the rural location on weekends; so they raise the demand for sophisticated goods and services locally but are nonetheless still rooted in a London-based economy.

What is particularly interesting about these emerging edge city and edgeless city structures, however, is that they also defy the idea that only routine activities will be exported from the urban core. Very complex and un-routinised tasks in sectors such as R&D and engineering have also moved to office parks and other peri-urban locations in the past two decades (Coffey and Shearmur, 2002, p.372). In fact, in some ways the trend seems so pronounced that we are at the point where the *non*-emergence of suburbanisation in a high-skill sector can be taken to suggest an unusual dynamic at work.

Technology: One key effect of technology on firms—especially large firms—is the way that it enables them to better integrate their internal functions (Robinson, 1931 [1943], p.41), while also allowing them to better coordinate and manage external relationships (Gillespie and Robins, 1989, p.11). In short, technology extends the envelope of viable configurations for the firm. Today's firms should be able to exploit increasingly fine divisions of the supply chain and production process to yield new efficiencies. And the 'informational content' of work is also increasingly amenable to this type of management such that the innovative phase of product development can be centralised to take advantage of creative resources while the application phase is decentralised to exploit routinisation (cf. Hackler, 2000).

Technology also changes the balance between the 'complex' and the 'routine'. We can expect to see increasing outsourcing of tasks previously considered essential to the firm's operation, including ICT, accountancy, or even legal counsel (cf. Timmons, 2010). This process now encompasses not only routine administrative functions (Traxler and Luger, 2000, p.289), but also critical managerial and creative functions: a recent study by Economist (2009e) found that fully half of American 'temps' were professionals, and that the practice of temping (even if not exactly publicised) had even spread to the boardroom.

Hall (2002a, p.269) connects technological change to the outmigration of households and entrepreneurs, suggesting that it has made Howard's 'Third Magnet'—the Town--Country axis (see Figure 4.3)—more attractive to many. And clearly, the ability to remain in touch with clients using telecommunications is a major factor for small consultancies and freelancers working in these formerly remote locations. Equally, telecoms will be an important factor for large firms in sophisticated sectors: because of their size, they may still have shared dependencies—for skilled labour, for transport infrastructure access, etc.—and will thus be encouraged to exploit the advantages of colocation, but they will be able to do so in areas that might well have been very much 'out-of-bounds' a few years ago.

Figure 4.3: Ebenezer Howard's Three Magnets (1898 [2003], p.24)

The software development and services industries are good examples of this process: they are quite concentrated to the West of London, but many of them are, by historical standards, some distance from their principal clients. One of the attractions of regional centres such as Reading, Oxford, or Bristol seems to be that, thanks to the mix of universities and amenities, they are a good source of skilled labour and are also attractive to households seeking space for starting or raising a family. So unlike London, these smaller towns and cities do not need to try quite so hard "to reverse a strong tide of people who show every sign that they want to escape the cities—above all, young parents with children, who have very negative perceptions of urban life and urban education" (Hall, 2002a, p.268).

Spatial Implications

For firms, the advantages to relocation out of the Central Business District (CBD) include lower rents for newer space, and reduced staff costs. In fact, even back in an era of more expensive communications and travel, reducing these costs represented a substantial savings: in 1975, the monetary costs of communication averaged only 8% of overall office costs, compared with 73% for staff costs and 15% for rents (Goddard, 1975, p.40). The greatest savings came to firms that moved between 50 and 100mi. from central London (1975, p.40), and decentralisation was seen as a normal part of office reorganisation as certain functions were "hived off" to less expensive environments (1975, p.35).

Returning to the life-cycle concept, before transactional patterns stabilise there is likely to be a 'window of locational opportunity' in which no one location or subset of possible locations has a decisive competitive advantage because significant place-based economies of scale have not yet emerged. Furthermore, in sectors where economies of scale are more modest and where differentiated production makes it possible for new entrants to compete with incumbents, then there may not only be many windows, but new windows may open on a frequent basis (cf. Scott and Storper, 2003, p.584). This dynamic may therefore give rise to a locational life-cycle of sorts in which the concentration of industry changes over time: dispersed during the early stages of sectoral or product development, then narrowing to just a few points with decisive location advantages, before eventually broadening again as the pattern of interaction stabilises (Menzel and Fornahl, 2010, p.3).

The issue facing specialised producers, which harkens back to the central place structure discussed in Chapter 2, is that large volume outputs require large markets into which to sell. Storper and Venables (2002) suggest that if the output is destined for final consumers then access to big cities will be a priority, but that if the firm produces an intermediate output then they will prioritise access to specialised cities "which concentrate large numbers of demanders of relatively specialised kinds of input" (2002, p.6). However, we need to qualify this prediction by noting that the complex supply chains supporting firms such as Zara or Benetton enable them to sell rapidly-changing clothing lines at shops all over the world without the need to have factories anywhere near the final market. To some extent, one could argue that integrated distribution and supply management systems have replaced physical plant as the key competitive asset of many large firms.

Summary

This review of scale economies has emphasised an essential difference between localisation and urbanisation economies: localisation economies are typically tied to the participation of firms in predominantly client/supplier relationships within a single sector, while urbanisation economies are tied to the participation of firms in several such relationships across *different* sectors simultaneously. And we can also now see how the stage of development of a firm or sector affects the extent to which it is able to exploit internal and external economies of scale; however, we have also highlighted the challenge facing entrepreneurs as they do so: while multiple optima indicate that the firm can pursue multiple routes to growth, the configuration of these optima may constrain the number of viable strategies.

For instance, Das and Finne (2008, pp.161–162) found that localisation effects contribute to the rate of growth in mature industries, while the externalities associated with urbanisation economies were more important for young sectors and businesses. And the differential impacts extend to the sector in which a firm operates: manufacturing industries appear to be negatively impacted by the diversity of urban environments, while service and high-technology firms appear to benefit (2008, p.162). In sum, perhaps firms in sectors with high rates of growth or innovation benefit from diversity because, on a pragmatic level, they simply do not know in advance what specialist inputs they will require or what new opportunities might suddenly appear. Conversely, established large firms tend to benefit from more incremental approaches, and the greater stability of their operating environments enables them to formalise their relationships in ways that reduce spatial dependence.

In fact, the benefits and disbenefits of agglomeration extend down to the level of the units of the firm itself. In the case of management functions, Scott (1986, p.225–226) argues that there is a tendency to locate in 'disintegrated complexes' with access to the specialist support services that might be required on a regular basis. Conversely, in the case of low-skill functions, it is often desirable to develop integrated facilities in more remote locations where labour is relatively less expensive (1986, p.226). Finally, in the case of skilled but non-managerial tasks, Scott predicts that they will gravitate towards secondary centres with desirable amenities (*ibid.*).

The role of transportation and technology change within this overarching framework is complex: cheaper transportation and communication will tend to shorten and disrupt product life-cycles by 'increasing reactivity to the market and cheapening upstream relationships in commodity chains' (Storper and Venables, 2002, p.33). However, travel and telecoms also enable firms, and especially MNEs, to more effectively integrate dispersed operations and generate additional economies of scale even in historically complex tasks such as accounting or financing services (Nachum, 1999, p.22).

4.3 Agglomeration

In the previous chapter we considered several reasons for localised specialisation; in this chapter we're examining in more detail the reasons that these producers concentrate in particular spaces and districts. The importance of agglomeration to regional and national economic development can be gauged from the fact that 40% of American employment was found in counties making up just 1.5% of the country's land area (Scott and Storper, 2003, p.581). The importance of such small areas to overall American employment would appear to suggest that agglomeration has an economic benefit (Cook et al., 2007, p.1325), and in the above sections we have considered several factors that might play a role in this outcome. Here we will examine the agglomerative process in more detail so as to better understand its causes and effects, as well as the potential disbenefits that might eventually ensue.

Surprisingly, our ability to distinguish an agglomeration from, say, a localisation economy immediately runs into the limitation that comparatively little has been added in the past hundred years to Marshall's basic three-part outline of the advantages of agglomeration: access to a large pool of specialised labour; access to specialised suppliers; and access to "knowledge with the characteristics of a public good" (Cook et al., 2007, p.1326), or as Marshall originally put it: access to places where knowledge is "in the air" (1890 [1948], p.271). For reasons that will become clear in the subsequent section on clustering, I will argue that the 'in the air-ness' of knowledge is a feature of clusters, but not necessarily of agglomerations. Instead, I suggest that we should supplant this last part of Marshall's definition with the idea that "…agglomeration consists of different sectors sharing common input structures and clients" (Storper and Venables, 2004, p.365), and that it is therefore characterised primarily by market relationships.

Types of Agglomeration

Using this definition, and building on the findings from the previous section on the impact of scale and life-stage, we can see how agglomeration can occur along two axes: vertical and horizontal. Vertical agglomeration is connected to the economic benefits resulting from the proximity of one or more stages within a single supply chain, while horizontal agglomeration occurs when competitors and/or collaborators who are *not* necessarily engaged in direct input/output relationships derive some benefit from being concentrated at a single location. Clearly, horizontal and vertical agglomeration can occur both independently and concurrently, and the predominance of one or the other can be connected to the impact that scale and life-cycle have on the optimal corporate and sectoral configuration.

As we saw in Chapter 3, the proximity of customers and suppliers offers advantages to firms by acting to suppress the costs of market coordination (see page 98). For example, the Economist Intelligence Unit (2006, p.58) quotes a specialised manufacturer of steel products who indicates that: "A factor in locating our manufacturing is availability of raw materials. China and Taiwan cannot supply, and as we are based in Europe, we are close to key suppliers in Germany and France." In a similar way, as producers of specialised labour and information outputs universities "provide a non-mobile, valuable, and restricted input to production" (Lösch, 1954 [1973], p.83) that may also spur agglomeration. The point is that high levels of specialised demand or supply encourage an increasing specialisation of labour and production in a region, and this, in turn, "opens new ways of doing business and opportunities not recognised in more integrated production methods" (Cook et al., 2007, p.1327).

In contrast, horizontal agglomerations place competing firms within the same industry together, usually for the purpose of making themselves 'collectively available' to potential customers (Scott, 1984, p.13). There is obviously a good deal of overlap between the concept of the Central Place and horizontal agglomeration: in both cases, economies of travel for buyers give agglomerated firms access to more potential customers. However, because the firms do not necessarily serve the same sets of clients, or may serve many different types of clients, we would expect to find greater diversity in the technologies and processes employed. This inter-firm variation has two important benefits: observability, in which a firm can more easily monitor and copy what its competitors are doing; and comparability, in which a firm can more easily benchmark its own output against other approaches (Cook et al., 2007, p.1327). Survey results by Cook et al. (2007, pp.1334–1338) from the City of London suggest that horizontal agglomeration is important, but that the benefits are not seen as clearly by firms as they are for vertical agglomeration.

Conceptual Challenges

There are, however, several important conceptual challenges connected to the identification of an agglomeration. The first, and most important, is the problem of scale: what density of firms, and over what geographical extent, is required to create an agglomeration? Do they, for instance, occur only at the neighbourhood scale, or do they span cities, or even entire regions? Coe and Townsend (1998) have argued that small scale, localised agglomeration in the U.K. is largely a myth—though they also note that the obverse, that only global forces are relevant, is equally fallacious—and suggest that the appropriate analytical unit is really the entire Greater South East of England (GSE) region.

A second factor is that some longitudinal measures of agglomeration may be quite misleading because they are not like-for-like comparisons. For instance, many metrics indicate that financial services have become more concentrated with time; but this may in part be the result of changes in what financial work actually is: the vast branch networks of the 20th Century have been largely replaced by ATMS (Coffey and Shearmur, 2002, p.376). For banks, most tasks are now performed in just three places: the head office, the back office, and the call centre, and so increasing concentration may be driven by the redistribution of work alone and not by an increase in the benefits of agglomeration. In short, the seeming concentration of some activities may largely be the result of measuring an increase in spatial monopoly—the fact that only one firm can occupy a given point in space.

An additional consideration is the extent to which power relationships between firms and infrastructure operators can impact the overall distribution of activity while being misleading as to its underlying causes. In a study of the transoceanic shipping network, Fowler (2006, p.1430) points out that agglomeration effects seem to be driven not so much by positive externalities as by the competitive strategies of the ports to lure business away from other points of entry. Moreover, the largest shipping firms are fully aware of their market-making power, and force ports to offer higher levels of service by threatening to take their business elsewhere (*ibid.*). So "some portion of the observed agglomeration may have little to do with current benefits to locally embedded business interests: instead, agglomeration can come from technological advancements and strategic decisions on the part of actors in networks who are not necessarily tied to the cities that they connect" (Fowler, 2006, p.1436).

Finally, a review by Athey et al. (2007, p.27) found that some cities seem to benefit from a kind of 'supply push' in which the "supply of innovative goods and services actively shaped markets, rather than simply responded to consumer demand." Hall argues that Silicon Valley, through the growth of the venture capital industry (1998, p.452) and 'influx' of researchers from Stanford (1998, p.495), and Detroit, before scale manufacture of automobiles wiped out its diversity (1998, p.489; see also page 125), both displayed this characteristic and notes that "many of the innovative milieux seem to have begun by catering for what could be called an internally generated demand" (1998, p.495). This would fit with an assertion by Storper and Walker (1989, p.71; reported in Cole, 2008, p.900) that "contrary to Weberian theory, industries are capable of generating their own conditions of growth in place and making factors of production come to them…or come into being."

Transportation & Technology

Demand for information-oriented services has produced a boom in highly-specialised SMEs and 'boutique' consulting firms (cf. Beyers, 2000; Hall, 2007b), some of which report operating in markets with as few as five serious competitors (Keeble et al., 1998, p.331). From a traditional business development standpoint, many of these boutique firms follow a rather unusual developmental path: their markets are so specialised that they must be effectively 'born global' in order to have a sufficiently large market for their very particular offerings (Hall, 2007b, p.1850). Consequently, for highly-specialised firms an internationalisation strategy rooted in global travel and telecoms is essential to survival (Keeble et al., 1998, p.327).

However, the same process that enables these firms to access clients globally also brings them into competition with similar firms elsewhere in the world. To remain competitive, these SMEs must leverage not only their global linkages, but also any local sources of innovation that might act as a source of competitive advantage (Keeble et al., 1998, p.333). This dynamic would seem to be the reason that 'internationalised' SMEs surveyed by Keeble et al. reported that collaborations with universities and with firms in the same overall line of business were vital to their success and why they spent more time and money actively cultivating research and development contacts than their less outward-looking counterparts (1998, pp.335–337).

For larger firms, the combination of ease of communication and ease of movement for employees based in the leading world cities creates the possibility of a firm that is simultaneously spatially-diffuse but still vertically and horizontally integrated, and able to benefit from local agglomerations at the level of the individual office. In other words, improvements in travel and telecommunications make it possible for the firm to coordinate activity within a mix of real and electronic spaces that constitute what Audirac (2002, p.218) calls a 'hybrid' space, and the deployment of ICT within MNEs suggests that they are making particularly extensive use of this hybrid environment.

Revisiting the operative definition of agglomeration, we can see that none of the three elements—specialised labour, specialised suppliers, and common input structures and clients—actually *requires* the continued spatial proximity of firms, though this would be a natural assumption. In short, we need to better-distinguish between geographic dispersal and functional decentralisation (Goddard, 1975, p.54). This possibility will be considered in more detail in sections 4.4 and 5.3, but it is the tension between these two forces which generates the basic question—as raised by, amongst others, Sassen (1991)—of whether management functions will continue to agglomerate at strategic global locations, or whether this technology-enabled hybrid space will enable a re-diffusion of this coordination function?

Spatial Implications

Like many others, Scott and Pope (2007, p.1365) argue that large, dense industrial agglomerations have always been sites from which routine or low-value work has been 'expelled'. Evidence from the City of London would certainly appear to support this: while low-value and back office activity have already moved out (Cook et al., 2007, p.1343), the problem of information interpretation seems to have forced the most-skilled workers together in order to manage the almost overwhelming flow of market data and information (Gillespie and Richardson, 2000, p.234). Predictably, we also find that some areas of the cultural economy, such as pre- and post-production, which have "transaction-intensive structure and highly-specialised labour requirements" (Scott and Pope, 2007, p.1366), are also heavily concentrated in the city-centre.

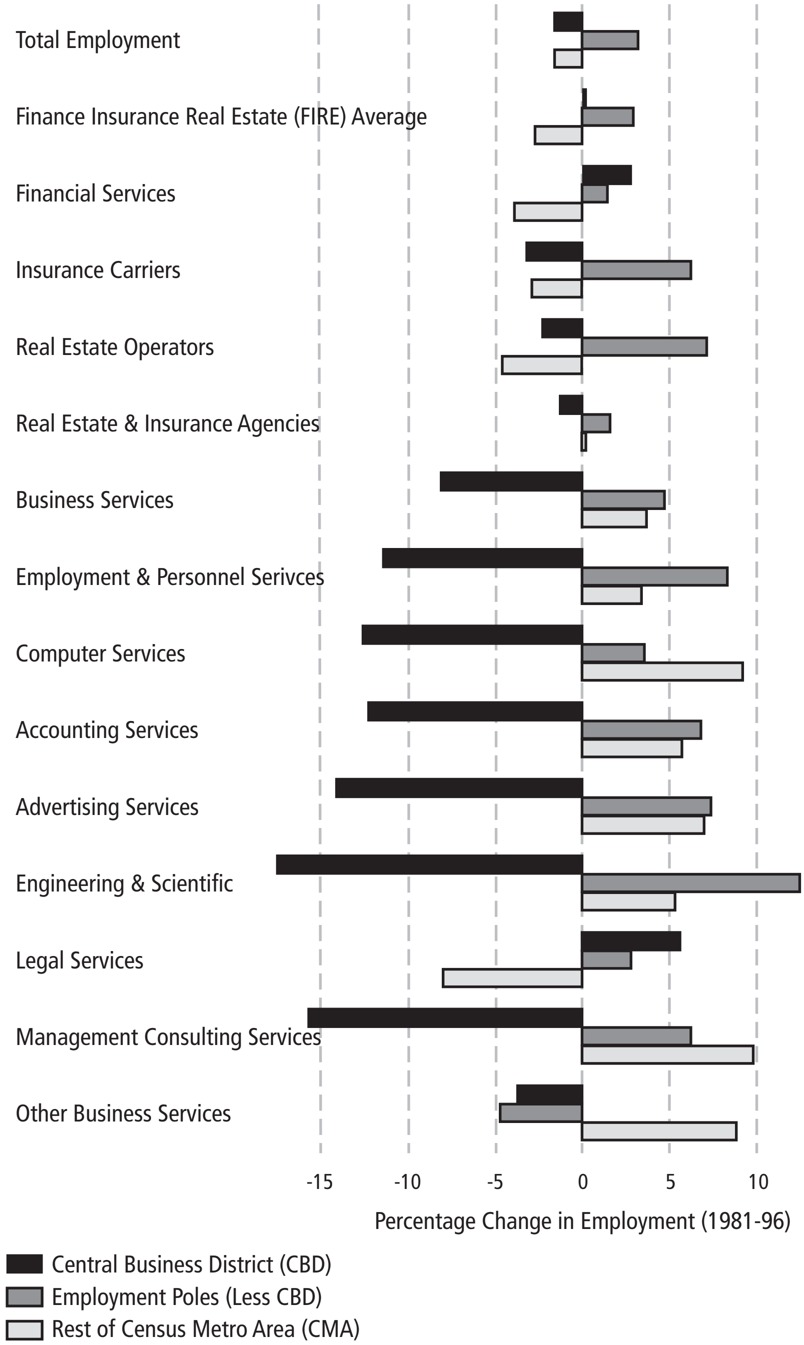


Figure 4.4: Changes in Share of Montreal Metro Area Employment (Coffey and Shearmur, 2002, p.371; reproduced with permission of Sage Publications)

We've noted above (see page 127) that some firm decisions may be driven by workforce migration to the suburbs and the need to set up offices at accessible locations outside the CBD. What is particularly intriguing from an planning perspective, however, is that the relocated work has not been randomly distributed around the region and still seems to end up in concentrated in particular areas (Gaschet, 2002, p.65). Evidence from Atlanta suggests that edge-cities are in some sense the recreation of the CBD on an accessible metro fringe (Leigh, 2000).

What seems to be happening is that these emerging subcentres are nearly as specialised as the CBD zone they encircle, but that they are specialised in *different* sectors from the urban core. So in the examples from France, the 'economic base' of the subcentres is systematically biased towards manufacturing, construction, and transportation, and against personal and collective services (Gaschet, 2002, p.78). Similar study of the Montréal region found that, although all centres and subcentres were specialised in at least one high-value service, the CBD was relatively more specialised in *all* high-order services (Coffey and Shearmur, 2002, p.367), with the notable exception of science and engineering services and an increasing decentralisation of the Accounting and Management Consulting sectors (2002, p.368). Figure 4.4 gives us a sense of how these trends have developed over the past decades.

However, the sheer cost of major infrastructure remains one reason that physical proximity is attractive to firms with such dependencies (Coffey and Shearmur, 2002, p.361; and see also Hall, 2009, p.807). A particularly topical analysis by Bettencourt et al. (2007) of the relationship between 'urban indicators' and city size in America quantifies this effect very clearly: infrastructure, such as roads, electrical cable, and petrol stations, scale *sublinearly* with city size, while other aspects of cities such as patents, wages, and crime, scale *superlinearly*. The terms superlinear and sublinear here refer to the exponent β in the equation $Y(t) = Y_0 N(t)^\beta$ where $N(t)$ is the population of a city at time t, Y_0 is normalisation constant, and $Y(t)$ the indicator of interest.

Y (Urban Indicator)	β	Country & Year
New patents	1.27	U.S. 2001
Private R&D employment	1.34	U.S. 2001
'Supercreative' employment	1.15	U.S. 2003
New AIDS cases	1.23	U.S. 2002–2003
Total housing	1.00	U.S. 1990
Household electrical consumption	1.00	Germany 2002
Household electrical consumption	1.05	China 2002
Gasoline stations	0.77	U.S. 2001
Length of electrical cables	0.87	Germany 2002
Road surface	0.83	Germany 2002

Table 4.1: Scaling exponents for urban indicators (adapted from Bettencourt et al., 2007, p.7303)

In plain English, when $\beta < 1$ a doubling of a city's size does not double the indicator, but if $\beta > 1$ then doubling the city's size *more* than doubles the indicator. In terms of our discussion of the benefits of agglomeration and of urbanisation, Bettencourt et al.'s (2007) analysis demonstrates the substantial cost advantages of deploying infrastructure in urban locations since the 'circulatory' indicators all have $\beta < 1$ (see Table 4.1). However, the summary table *also* suggests that there are measurable productivity and creativity advantages to urban locations since they all have $\beta > 1$. We will approach the 'superlinear' indicators indirectly later, but for now let us note only that these all seem to be characterised by *network effects*.

Summary

So on the one hand we have "continuing pressures towards agglomeration, includ[ing] available skilled labour, universities and colleges, and [the] availability of specialised training resources" (Traxler and Luger, 2000, p.288), but on the other hand we have increasingly sophisticated methods for enabling functional agglomeration to supplant or complement geographic concentration. The ability of technology to enable coordination at a distance and to reduce transaction costs suggests that proximity should no longer be considered a necessary precondition for agglomeration, and our revised definition emphasises this change.

So, the coordinative changes enabled by ICT should encourage us to put more focus on the possibility that 'virtual agglomerations' of firms may emerge which have no corresponding geographic manifestation (Traxler and Luger, 2000, p.286). Firms and individuals can now coordinate bidding and purchasing electronically, reducing the barriers to entry and increasing the scale over which informational and material flows can be managed. Technology thus serves here to increase the transparency of markets, making search and match processes more efficient, and reducing the cost penalty exacted by space on both stages of a transaction.

Locationally, we may anticipate some level of path-dependency, with 'new economy' firms exercising greater freedom of choice than their more established counterparts; some will pick their location "on the basis of access to airports and highways, where those opting for exurban and rural locations do so for quality-of-life reasons" (Audirac, 2002, p.221). However, while some sectors are relocating over large distances, others seem barely to be 'moving down the road' even if they are no longer strictly based solely in the CBD (Audirac, 2002, p.216). The question is this: *why* has growth in the highest-order sectors occurred primarily in the CBD? And why are engineering and R&D seemingly following a different trajectory? Section 4.4 begins to offer an answer to this question, and Chapter 5 will attempt to flesh out a response to these seemingly contradictory trends.

4.4 Clustering

In *Book X* of his *Principles of Economics*, Marshall (1890 [1948], p.xi) observed that in some rare cases concentrations of industry emerge that, while exemplifying "a 'general rule' of differentiation combined with integration" like an agglomeration, also create an environment within which "the mysteries of trade become no mysteries; but as it were in the air..." (Marshall, 1890 [1948], p.271). Marshall's observation points to the idea that in particular times and places the 'secrets' of a profession may be socialised and a *culture* of collaboration arise and thrive within a shifting framework of nonetheless cutthroat competition.

A more precise definition of what we now call 'a cluster' was given by Nachum and Keeble (2003a, p.173), who defined it as a "geographically concentrated group of competing, collaborating and independent firms connected by a system of market and non-market links." The existence of 'non-market interactions' is the key to defining a cluster of firms in a way that is meaningfully different from 'mere' agglomeration; and we can make use of social network analysis to get to grips with what is happening within clusters since "conceptualisations of networks remain fairly basic in economic geography and are largely focused at the inter-organisational level…" (Grabher, 2004, p.105).

The reason this distinction matters is that clusters are thought by many policy-makers to demonstrate high rates of innovation and new business formation, and they have invested a great deal of money in trying to recreate the success of Silicon Valley—as documented by, amongst others, Hall and Markusen (1985), Hall (1998), and Saxenian (1990, 1994, 2000)—elsewhere around the world. Martin and Sunley (2003) and McDonald et al. (2007) suggest that some policy-makers are inclined to see clusters everywhere: in his opening remarks at the *World Congress on Local Clusters*, the Secretary-General of the OECD asserted that by the mid-1990s the U.S. contained some 380 'local clusters' that collectively accounted for 60% of America's industrial output (Johnston, 2001).

However, the difficult experiences of many countries in trying to manufacture 'technopoles' on the Silicon Valley model (cf. Castells and Hall, 1994), makes the notion that there is such a profusion of clusters in America, or indeed anywhere, profoundly problematic. The experience of Tsukuba (Castells and Hall, 1994, pp.65–76) and Sophia-Antipolis (1994, pp.85–93) highlights this: neither has produced many spin-offs nor entrepreneurs, and the principal attraction for firms has been policy-generated, such as access to national lab facilities or tax incentives, rather than sustained innovation (1994, p.70).

Clearly, the fact that Silicon Valley is a shorthand for high-tech success is in part a function of size: San Jose grew from 95,000 to more than 500,000 people in the space of just 25 years (Hall, 1998, p.449), and today there are more than 500,000 working in 'high-tech' jobs alone (Thibodeau, 2009). In contrast, Sophia-Antipolis—in spite of being Europe's largest 'innovation park'—had just 26,000 workers as of 2003 (Fondation Sophia Antipolis, 2006). But California's association with innovation also stems from the fact that, whereas Silicon Valley is composed of firms at all stages of growth and is a hotbed of start-ups, Sophia-Antipolis has historically been dominated by large firms with an aversion to collaboration and owes its very existence to direct government intervention (Hansen, 1990). This is *not* to suggest that the French office park is a failure—it is now a nationwide leader in R&D activity (Lazaric et al., 2004)—but that something qualitatively *different* happened in California that did not happen in the Côte d'Azur.

Defining a Cluster

According to Cooke's review (2001), these divergent outcomes hinge on the fact that little in the way of dynamic, local learning systems emerged in the French business park: the majority of relationships were vertical (supplier/buyer), learning partnerships were minimal, and the local labour market was quite weak, meaning that employees tended to stick with the large firms rather than leaving to form start-ups. In short, Sophia-Antipolis was an agglomeration of firms with few of the cross-cutting inter-organisational relationships (iors) that characterise information- and exchange-rich environments like the one in Silicon Valley (cf. Knoben and Oerlemans, 2008, p.388). It is not that clusters do not have market-based exchanges, they do (Menzel and Fornahl, 2010, p.16), but that this is not a defining characteristic.

As connections between individuals and firms proliferate, they create disincentives to relocation: economic agents will naturally hesitate to disrupt stable iors, particularly those which support growth and innovation (Knoben and Oerlemans, 2008, p.389). So what we are saying is that the "spatial proximity of large numbers of firms locked into dense networks of interaction provides the essential conditions for many-sided exchanges of information to occur" (Scott and Storper, 2003, p.583), and that these exchanges serve to 'lock in' firms to particular districts. However, the nature of these networks needs to be examined in much more detail before we can begin to establish why "geographically concentrated companies…exhibit a disproportionately high innovation rate during the growth phase of the industry" (Menzel and Fornahl, 2010, p.3).

Formal & Informal Networks: Generally speaking, the study of business networks within regions has been seen as the study of informal personal networks; however, Lawton-Smith (2010) points out that formal networks also exist and may play an important role for younger firms. The distinction between formal and informal interactions gives rise to three basic network-types: formal firm-based business networks designed to foster 'resource formation and exploitation' in supplier/customer-type relationships; formal professional networks where employees meet 'for personal and professional advancement'; and informal open networks of personal interaction with no specific sectoral affiliation (2010, p.6).

As an example of this, the Oxford-to-Cambridge Arc (o2c Arc[6]) contains no fewer than 221 networks of varying types and sectoral orientations, with sources of support that range from participant-subscription to government- and eu-funded initiatives alongside less formal configurations (Lawton-Smith, 2010, p.6). Publicly-funded networks seem to predominate where there has historically been less start-up activity, while private and academic networks are more common in Oxford and Cambridge, both areas with longer innovation histories (Lawton-Smith, 2010, p.8). In line with Saxenian's study of Silicon Valley (1994), the prevalence of business networks is here connected to higher rates of innovation—Oxfordshire, Cambridgeshire, and Milton Keynes outpace 'less connected' adjacent regions such as Bedfordshire and Northamptonshire (Lawton-Smith, 2010, p.6)—but what is notably different here is that formal networks are the dominant type (2010, p.7).

[6] This term actually appears to have originated with a coordinated initiative by three Regional Development Agencies (East of England, East Midlands, and South East of England) in support of technology-sector activity in 2003, but it has now gained wider currency as a generic term for new business efforts in the area bounded by the two cities (cf. The Cambridge Network, 2003).

Participants in Lawton-Smith's research connect involvement in formal networks to benefits including increased sales, collaboration, legitimation, and representation (Lawton-Smith, 2010, p.5). So we are not dealing solely with effects on innovation, and although the latter two advantages seem to have been less-studied, they are clearly also important to emerging industries: European animators used a major industry conference as a formal professional networking environment (Cole, 2008), and boutique financial firms created a formal alliance through which to promote their specialised services to potential clients outside of their existing personal contact network (Hall, 2007b, p.1848).

The history of the Homebrew Computer Club amply demonstrates the value of a mix of fora for networking: 'formal' meetings to present new hardware or ideas were often followed by informal, 'random access' discussions, often at The Oasis bar and grill (Hall, 1998, p.443; Wikipedia, 2002). In a similar way, financiers, accountants, and consultants interviewed by Cook et al. (2007, p.1336) report that proximity to social venues is an important factor because it offers access to industry gossip and insight into key market movements (Cook et al., 2007, p.1336). And as many of these fields are characterised by high staff turnover—on average, professionals in New York and London's legal and advertising markets had worked for three different firms— workers see staying in touch with past colleagues as "a valuable way of participating in discussions about shared [challenges]…typically through infrequent lunches or after-work meetings…" (Faulconbridge, 2007, p.1644)

Torre has suggested that "geographical proximity is not an economic cause of agglomeration as much as a social effect of the embeddedness of economic relations" (Torre, 2008, p.878), by which he means that the localisation of 'innovation networks' may just be the product of our tendency to trust and collaborate with those who are closest to us socially and geographically. In other words, because our social connections tend to be more dense in our immediate vicinity than they are at a distance (Rychen and Zimmermann, 2008, p.769), the non-market links that characterise clusters mean that they were always destined to be local as well. Recalling the City of London in the 1950s and 1960s, one of the Bank of England's representatives says "I always reckoned you were idling if you were sitting at your desk in the Bank, I loved putting on my top hat and going round and dropping in on the banks and having a chat" (Kynaston, 2001, p.206).

We can expect an abundance of interaction to stimulate the formation of an extensive and well-connected network of contacts at the same time as it reinforces the idea of a 'community of learning' that is somehow greater than the sum of its participating parts. Indeed, there may be a sense of 'belonging' that flows from shared challenges and similar backgrounds (Storper and Venables, 2002, p.13), and this sense of being part of a group (especially one at the leading edge of an exciting industry) helps to establish social norms to which people will adhere in part "…to show that they have certain criteria of judgement, which in turn signals to others that they belong to a certain social world" (Storper and Venables, 2002, p.16). But the larger point I am making here is that while Silicon Valley and Wall Street are agglomerations in a classic sense, they are also fundamentally social entities in which a wide range of interactions, occurring both inside and outside of working hours, are crucial to their perpetuation.

Of course, this is not to suggest that staff run around sharing trade secrets willy-nilly[7], nor should we expect even notoriously uncommercially minded engineers to freely share insights into products or services that they are in the process of developing. The financiers interviewed by Faulconbridge (2007, p.1644) emphasised that "it was possible to describe a situation without divulging confidential material" and that therefore exchanges of information and learning could take place without compromising a firm or client. However, for such informal exchanges to occur, it is clearly important that the relationship between participants be characterised by some degree of trust: they must believe that their insights will be reciprocated at some point in the future (Morrison, 2008, p.821). In sum, Faulconbridge's interviewees pursue a cautious strategy of making one or two offers of insight which, if unreciprocated or unduly exploited by the recipient, would cease immediately (2007, p.1648).

[7] In fact, McCann et al. (2002, p.655) argue that in the semiconductor and pharmaceutical industries physical proximity between some suppliers and buyers may actually be designed to limit the likelihood of information leakage and so have little to do with new knowledge generation (2002, p.657).

Trust & Strong Ties: We can frame the structure of this exchange more formally using Granovetter's (1973, p.1361) definition of strong interpersonal ties as "a (probably linear) combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterise the tie." So the 'junior professionals' in finance who are expected to share their insights into the market with others within the firm are in the process of building strong ties rooted in their peers' and supervisors' recognition and respect (2007, p.1649). And because face-time is not fungible (*i.e.* substitutable), it is a signal of importance that is very costly to fake for highly-skilled workers. In fact, the personal costs "can be substantial, far outweighing the cost of the message" itself (Storper and Venables, 2004, p.356), and increasing profligacy only serves to "enhance the validity of the message" (Storper and Venables, 2002, p.26).

Historically, trust has been thought to play a particularly important role in the financial sector where "money is moved daily on the basis of advice or without the benefit of a written agreement but on the basis of understanding and custom" (Traxler and Luger, 2000, p.291). One City of London financier's memoirs indicate that in the 1950s he had underwritten agreements worth more than £2,000,000 (more than £35,000,000 in today's terms) with nothing more than verbal agreement and a note on a piece of paper (Kynaston, 2001, p.203). It may seem odd that a sector which at times focusses on advantages measured in fractions of a cent should also be so beholden to personal and professional relationships of trust, but the collapse of Bear Stearns in 2008 makes it abundantly clear what happens when there is a breakdown of the trust in financial markets (Economist, 2008b). In fact, it is clear that for many financial firms their reputation is their main competitive advantage: "Reputation—slow to gain, quick to lose—[is] integral to the reposing of trust" (Kynaston, 2001, p.203)[8].

A recent study of the 'boutique' financial industry in London highlights the changing nature of strong ties in the financial sector: because the boutique firms are small compared to the full-service investment banks with which they compete, it is not usually the boutique's name that closes a deal, but the individual and their reputation with the client (Hall, 2007b, p.1848). In the past, when bankers were uniformly drawn from an Oxbridge background, this established a 'shared biography' in which trust was implicit: "Good Etonian standards means a total trust—if you say you'll do something, you'll do it. On the whole, dealing with Etonians in the City, you had a sense of confidence that they would behave impeccably" (Kynaston, 2001, p.201). The decline of this uniformity in background and outlook, Hall suggests, has removed this shortcut to trust and forced these bonds to be 'actively manufactured' (2007b, p.1848).

[8] The more recent controversy around the role of Goldman Sachs in betting against financial products that it was simultaneously touting to clients has dragged the issue of trust back into focus (cf. Story and Morgenson, 2010).

The non-work environment seems especially important to the process of manufacturing strong ties:

> Knowing your clients is crucial…I was actually told that when I started here…like I went to the Six Nations [rugby tournament] with a client and that's how they come to trust you…you share your experiences with them and they see what you're like as a person, not a voice at the end of a phone line. Trust centres on me as a person as well as me as a corporate financier.
>
> *Associate at boutique firm (February 2003; reported in Hall, 2007b, p.1848)*

This last comment points to the importance of common frames of reference to building a kind of 'category trust' (cf. Grabher, 2002, p.210); a more diffuse type trust that may act as a platform for building interpersonal trust: "Interviewees suggested that feeling part of a defined local community encouraged collaboration and the sharing of ideas and insight with individuals at rival firms" (Faulconbridge, 2007, p.1650).

Granovetter's ground-breaking paper on social networks showed that if an individual has two trusted friends, then it was highly likely that that these two individuals *also* knew each other and were friends as well (Granovetter, 1983, p.1362). And given the obvious importance of trust to the efficient operation of opaque markets, it might seem that weak ties would be irrelevant to the operation of clusters. However, Granovetter's crucial insight is that strong ties in social networks can have negative economic effects if they yield a lack of exposure to 'novelty'. While strange on the surface, this result stems from the fact that strong ties—on account of their socioeconomic similarity—are likely to be found between individuals who are already part of a tight-knit group, whereas weak ties will by definition tend to be found between dissimilar groups.

Innovation & Weak Ties: Because weak ties are more likely to "connect individuals who are significantly different from one another" (Granovetter, 1983, p.204), they will tend to bring together people who have been exposed to different information about their environment.

The evidence from Granovetter's research was that blue collar, professional, technical, and managerial workers *all* tended to find out about job opportunities through people they saw only occasionally (55.6%) or rarely (27.8%), and that new information was more likely to come from "an old college friend or a former workmate or employer, with whom sporadic contact had been maintained" (1973, p.1371)[9]. Perhaps nowhere have these dynamics been seen to be more important than in the market for cultural and innovative high-technology goods where "social and professional networks [are] not simply conduits for the dissemination of technical and market information. They also [function] as efficient job search networks" (Currid, 2007, p.73). As a result, many firms actively exploit such networks "as [a] source of recommendations and referrals for hiring" (Nachum and Keeble, 2003a, p.181)

[9] In fact, the only people for whom strong ties proved to be important as a source of employment opportunity were those in periods of great uncertainty and stress, such as after a period of unemployment, which suggests that we may only feel comfortable drawing upon close friends in an active way (1973, pp.211–212), even though it is our acquaintances who are most likely to be useful to our search.

In the literature review of their 2007 investigation, Hauser et al. (2007) cited empirical support from a variety of sources for the application of social network theory to economic development, stating that "after controlling for trust, weak ties exert a stronger effect on successful knowledge receipt than strong ties" (2007, p.78). In their own work with human capital data collected by Eurostat, Hauser et al. (2007) found that innovation was correlated with two dimensions of 'social capital': Associational Activity, which they took as a proxy for weak ties, and (to a lesser extent) Political Awareness, which they interpreted as a proxy for an outwardly-oriented disposition towards the world; trust, it seems, played little role in the degree of innovation (2007, p.83–84)[10].

[10] However, the authors note that the survey used to generate the results phrased trust in negative terms along the lines of 'how do you feel about people who don't look like you?' (Hauser et al., 2007, p.84)

According to Torre (2008, p.871), Schumpeter's model of innovation 'bundles' had groups of entrepreneurs emerging at the same time and place when both their technology and their ideas had reached some level of maturity. However, the next and crucial step to self-sustaining innovation may only be possible if some level of reciprocality between weakly-connected individuals is possible. This type of relationship undoubtedly exists in Silicon Valley, where engineers engage with difficult problems *beyond* the boundary of the firm largely for the reputational effects. However, I suspect that it also exists in a slightly different form in the fashion and financial centres of New York and London: the need for constant innovation, combined with the need to work with specialists in other different sectors in order to deliver a product or service, requires employees to maintain extended circles of acquaintances upon who they can draw for insight and assistance on short notice, often in ways that preclude extensive formal negotiations or alliances.

Multi-scalar Social Networks

Although it might seem that these social network effects can operate only at the local level, an analysis of the Soho advertising industry cluster by Nachum found that it was "far from being self-contained and isolated" (1999, p.36) and that local linkages, while 'vital for competitiveness', were "insufficient by themselves to gain access to expertise and knowledge which are increasingly shaped on a global basis" (1999, p.4). It was not that international networks supplanted local ones, rather they complemented them "as a route for the circulation of information and expertise" (Keeble and Nachum, 2002, p.84; and see also Rychen and Zimmermann, 2008, p.767). This may well be why research amongst British SMEs found that firms with a more international outlook not only valued their local links more than domestic firms, but were also more likely to actively develop them (Keeble et al., 1998, pp.335–337).

So how does this complementarity operate at these very different spatial scales? Storper and Venables (2004, p.356) have suggested that the circulation of information occurs at two levels: a globally mobile network of top executives, creatives, and scientists, and a more localised network of professionals within a unique socio-cultural context (see Figure 4.5). Logically, in this model we would expect to find information being funnelled between local clusters through the 'elite' who span the two scales; and while we would tend to associate these people with Multi-National Enterprises (MNEs), there is no reason why this type of mobility should be restricted to MNEs alone.

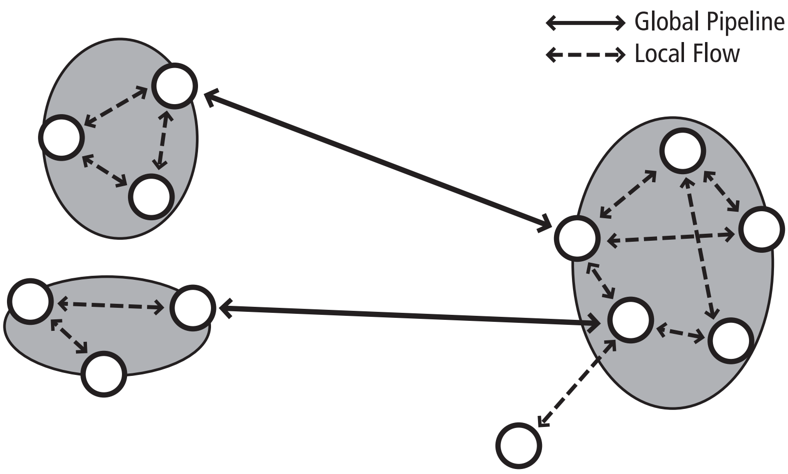


Figure 4.5: Pipelines & Gatekeepers

This slightly binary view of social interaction led some researchers to speak of 'pipelines' between agglomerations being essential to the circulation and acquisition of knowledge (Cook et al., 2007, p.1337). The basic argument is that the global pipelines enable a cluster to identify and take advantage of remote informational inputs (Rychen and Zimmermann, 2008, p.768). In terms of what these pipelines might look like, Rychen and Zimmermann (2008, p.770) propose three types: a permanent interface (*i.e.* an office) which collects information directly; a gatekeeper configuration in which a designated individual or organisation collects and distributes information; and temporary proximity created at trade fairs or industry expos.

There seem to me to be several basic challenges that Rychen and Zimmermann's model does not address directly: first, the office model presumes that the 'space of the firm' is fully-integrated and that information flows smoothly from one office of a MNE to another; second, the gatekeeper approach suggests the emergence of a hierarchical organisation within what is an essentially unstructured and complex process; and third, the idea that temporary proximity (which we will discuss more extensively on page 177) permits efficient knowledge transfer between clusters seems to assume that participants are inclined to share competitive advantages in this way.

To date, the gatekeeper approach seems to have garnered the most attention, and some have argued that for this process to occur some kind of 'translation' mechanism must be at work (Morrison, 2008, p.818). Evidence for this process seems to come from a study of Italian industry, which finds that the most innovative firms "devote significant efforts to search and translate knowledge coming from external sources, including universities and sectoral research centres" (Morrison, 2008, p.818). The idea here is that gatekeepers draw on "a high degree of relational capital" (Morrison, 2008, p.820) to identify, interpret, and absorb the information from external resources before 'translating' it into something useful to the local cluster.

While elegant, my suspicion is that the gatekeeper metaphor unduly privileges one set of individuals or firms in the flow of information through clusters. The evidence from internationally-oriented SMEs seems to suggest that *formal* collaborations between firms may well be so structured because not all companies see the same value in establishing international links; however, this is *not* the same as arguing that clusters—which I've argued are profoundly social in nature—are so organised and, additionally, the evidence at the interpersonal level is naturally much more mixed. So while it may be helpful to note that some firms are more active than others in exploiting external information flows, this suggests only that it would be dangerous to treat a cluster as a kind of soup of interchangeable firms.

Network science outlines two mechanisms by which information can propagate quickly and extensively without the need to promote a few key nodes to 'gatekeeper status'. First, while geography is an important variable in social networks, it is not the *only* one: interviewees in multi-national law firms emphasised to Faulconbridge (2007, p.1643) the importance of long-distance links with colleagues doing the same job in a different office. Those distant colleagues are the quintessential weak ties—people with whom a worker may have sporadic contact—and are not some kind of formal acquisition channel. Here, the 'spacelessness' of ICT means that physical proximity may no longer be quite so strong a predictor of whether or not the ties across which information can flow exist between individuals.

Second, depending on the intensity and level of socialisation, people may be able to extract meaningful information without a single 'message' being actively relayed from one cluster to another. This second approach might be particularly important in markets such as film or technology where the 'players' are in constant flux and so the build-up of 'buzz' around individuals and groups signals to others that valuable activity is occurring (2008, p.769). The topic of buzz is dealt with separately below, on page 154, but I wish to emphasise here its role in the propagation of information through social networks and how it impacts the success of clusters.

Returning now to the idea that geography is not the only dimension of social networks, Watts et al. (2002) found that if we take a more complex approach to proximity and allow an individual to be 'close' to another by bonds of kinship, friendship, ethnicity, and occupation, for instance, then the result is a 'searchable' network of surprisingly small worlds. A study of the LiveJournal social networking site (Liben-Nowell et al., 2008, p.11623), found that although some 70% of friendship processes are geographically informed, "existing models that predict the probability of friendship solely on the basis of geographic distance are too weak to explain these friendships…" The Liben-Nowell et al. (2008) model of rank-based friendship has also recently been found to apply in landline phone networks as well (Quercia and Calabrese, 2010).

The broader point is that while technology does not annihilate geographically-based socialisation, it does make it more complicated—might virtual teams that rarely meet in person function effectively as global pipelines without the need for a hyper-mobile 'elite'? I do not wish to claim that global and local social interactions are functionally equivalent, but that from the standpoint of the individual, the global/local dichotomy is just *one* axis of distance. So a colleague at a remote location may still be *close* to an individual if they share, for instance, a similar educational or occupational background, and I would argue that this is the origin of the Faulconbridge (2007, p.1647) interviewees' claim that there is an important synergy between local and global communications.

A recent article in *Nature* opens up what I feel to be an important, alternative way of approaching this problem. In social network analysis we tend to focus on the nodes, using the links between them as a guide to grouping the nodes into unique communities. However, Ahn et al. (2010, p.761) rightly point out that "whereas nodes belong to multiple groups (individuals have families, co-workers and friends), links often exist for one dominant reason (two people are in the same family, work together or have common interests)…" As a result, they therefore propose that "[instead] of assuming that a community is a set of nodes with many links between them, we consider a community to be a set of closely interrelated links." This shift in focus is crucial: the community—of financiers, art directors, and scientists—is defined by its links, and it is the nodes—people who are *both* scientists and artists, for instance—bridge these groupings; so there are not just a few gatekeepers or translators, they are effectively everywhere.

Information Acquisition

Signalling & Screening: We have seen that both finance and advertising are industries where it can be "difficult to evaluate the quality of the service in advance, and sometimes even after the service has been provided" (Cook et al., 2004, p.10). In the terminology of Chapter 3 (see page 94), these are 'opaque' markets where trust plays an important role, and yet we haven't established how agents identify trust-worthy individuals to begin with. Fortunately, economics gives us two mechanisms for dealing with opacity: signalling, in which information is imparted indirectly, and screening, which filters out low-performing workers. Signalling occurs when an agent sends a non-monetary message to affect the result of a transaction; conversely, screening operates by attaching costs to participation in a particular group such that *only* a successful individual or firm would be willing to maintain the required level of effort (Storper and Venables, 2004, p.352).

Education is one way for an individual to signal 'worth', but this mechanism does not work for firms and so location has become an important way for them to indicate quality and credibility (Keeble and Nachum, 2002, p.82)[11]. The lack of 'procedural screening mechanisms' (cf. Storper and Venables, 2004, p.360) helps to explain why financiers attach a high value to addresses, with one stating that "we have an ambition to be an international bank and you can't be an international bank unless you have something in London" (Cook et al., 2007, p.1332). Similarly, the cost of a Soho office signals to potential clients that the firm is successful enough to be a credible supplier of marketing campaigns (cf. Nachum and Keeble, 2003a, p.183)[12]. In both cases signalling is helping to overcome both high search costs—screening a large number of possible partners—and the high cost of implementation failure—signalling the ability to complete projects successfully.

At the individual scale, social networks are very effective at performing this signalling and screening task: a 'hot' designer or filmmaker is talked about at social gatherings, and people are said to be 'in the loop'. So social networks offer a collective evaluation system that operates through "an informal network in which knowledge about other members of the group is shared and filtered" (Storper and Venables, 2004, p.356). To succeed, however, the network must be both small enough that members who fail to 'deliver' can be excluded—the "you'll never work in this town again" stick—and costly enough that only the best will bother—the "if you can make it here…" carrot (cf. Storper and Venables, 2004, pp.360–364).

And as Sinatra's paean to New York suggests, the costs and benefits of network participation can be substantial: although a successful firm or worker in the New York City or London can expect to spend a great deal of money on space and socialising, they can also expect to reap substantial rewards by virtue of being a 'New York-based' or 'London-based' designer, filmmaker, or consultant. Critically, colocation lowers the cost of making these social judgements since it both facilitates access for newcomers—they know exactly where they have to set up shop in order to be taken seriously—and lowers the cost of evaluation—in-group members do not have to travel in order to assess the suitability of a prospective member (Storper and Venables, 2004, p.365).

[11] At the interpersonal level, interviews conducted by Brown and O'Hara (2003) suggest that mobile workers also use space to signal their availability—using an office with a closed door was readily interpreted by colleagues as a need for privacy, while sitting at a desk near an office crossroads could be used to signal both presence and a willingness to chat (Brown and O'Hara, 2003, p.10). In a similar way, business meetings at coffee shops are assumed to signal rather strongly that the meeting is intended to be informal or off-the-record (2003, p.13).

[12] As Torre (2008, p.875) puts it: "one cannot ignore the importance of 'window dressing' effects through the association with a successful technopole or cluster," though this implies that some areas are desirable not because of the access that they offer to innovation and social networks, but because they are expensive and thus work as 'prestige' sites (cf. Castells and Hall, 1994, p.90).

Scanning (Active Acquisition): Of course, important information does not simply 'fall into the lap' of decision-makers, and must often be actively collected or cultivated. Goddard (1973, 1975), building on a model proposed by Thorngren (1970), connects the nature of information collection to the temporal horizon within which decisions must be taken. Although all of the processes in Figure 4.6 are occurring simultaneously, it can actually be most easily read from right-to-left: on the right are the 'orientation processes' concerned with the distant future and scenario-building (*e.g.* the ideologies and basic science); in the centre are 'planning processes' that seek to link together more likely, near-term environmental changes (*e.g.* the potential social values and knowledge); and to the left are the 'programmed processes' that govern the management of activities in the 'now' (*e.g.* the economic technological environment).

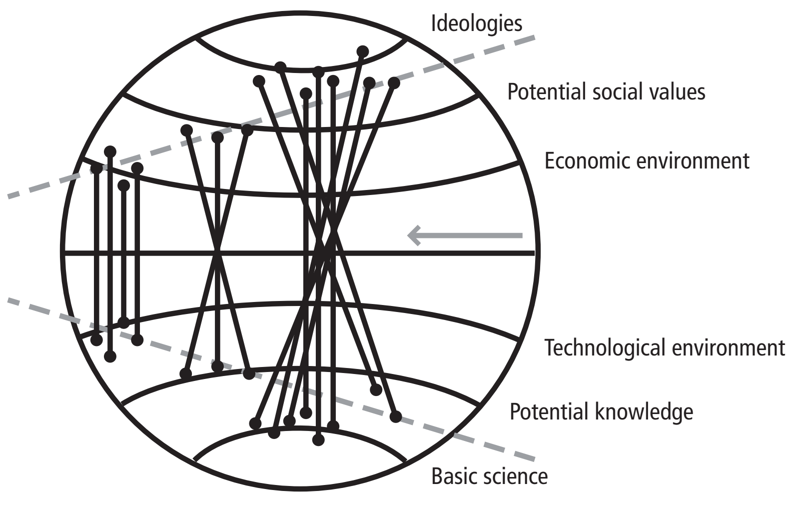


Figure 4.6: Contact patterns in the development space (after Thorngren; Goddard, 1973, p.191; reproduced with permission of Elsevier)

Using the example of a car company, Goddard (1975) offers a more concrete way of understanding this figure: at the orientation stage discussions might cover "changes to social values of personal mobility that affect viability of car itself"; in the planning stage the company might consider the development of a battery-operated vehicle; while the programmed, or control process would be concerned with the production of a specific model in the near term. Clearly, the output of one stage informs the requirements for the next, and Figure 4.6 suggests not only a narrowing of the horizon, but also a progressive structuring of the interactions between agents. And while the figure may appear to also suggest that there are more orientation than control contacts, Goddard indicates that programmed interactions are likely to make up the 'the bulk of the organisation's external relations' (1975, p.20).

There are two key assumptions of contact theory that we should dwell on here for a moment: first, that the degree of structure in the pattern of interactions increases as we move from right to left; and second, that the level at which each type of contact is presumed to occur also varies: from senior management, through middle management, and on down to the 'shop floor'. Goddard (1975, p.20) explicitly connects these stages to discrete spatial contexts: orientation contacts with research, government, and financing organisations, for instance, are expected to occur in the very largest urban centres because cities are the best venue in which to bring together the widest variety of contacts for a 'large, lengthy, and preplanned meeting' (1975, p.20; 1973, p.190).

In contrast, at the planning and control stages the participants are much more likely to have had prior interactions of some sort. At planning meetings, participants are expected to have more defined objectives and tasks to accomplish (Goddard, 1975, p.21), while programmed interactions are expected to be largely routine in nature and involve the giving and receiving of instructions. In both of these cases, Goddard suggests that telecommunications may substitute for some level of face-to-face (F2F) contact because the interactions are usually organised around an identifiable objective, instead of being for the purpose of identifying an objective in the first place. Interestingly, Goddard suggests that while programmed processes such as buying and selling could theoretically be organised entirely via telecoms, the sheer number of interactions might make this difficult, or even impossible, and that consequently programmed contact could actually be quite directly and negatively impacted by distance (Goddard, 1975, p.21).

There is an important spatial implication embedded in the idea that "the higher the administrative level in an organisation, the greater the proportion of staff time spent engaged in outward-facing contacts with other organisations (especially face-to-face)" (Gillespie and Green, 1987, p.400). Because urban areas have historically offered the broadest and deepest information space, we can expect to find the highest managerial levels in cities, while those with programmed functions and interactions are more likely to be found in lower cost regions. Furthermore, as firms diversify and innovate, their need for specialised external services increases (Gillespie and Green, 1987, p.401), reinforcing their dependence on the city as a source of business-critical inputs. Or to put it another way, "for *strategy*, we need organised information about the environment" (italics in original Drucker, 1999, p.121) and urban environments offer the best way to bring together and organise the diverse, uncertain information sources from which strategy can be built.

Although the findings are slightly dated, Goddard and Morris (1976) compare pre- and post-relocation contacts for firms moving out of London, and find that the movers had 58% fewer external calls and 62% fewer external meetings than the firms that stayed put. Firms that had already dispersed had 72% fewer external calls than the movers, but nearly 50% more internal meetings (see also Goddard, 1975, p.46). Crucially, contacts at the relocating firms were the most likely to be 'programmed', suggesting that these offices either had less need for strategic/orientation contacts, or played information-processing roles within their organisations. Conversely, the firms that rejected incentives to relocate had more 'orientation' (*i.e.* unprogrammed external) contacts (Goddard, 1975, p.48). These findings are summarised below in Table 4.2.

	Meetings per respondent		Calls per respondent	
	External	Internal	External	Internal
Non-Movers (*i. e.* remained in Central London)	1.6	0.8	9.0	5.3
Movers (*i. e.* left Central London)	0.6	0.2	3.7	5.5
Decentralised offices	0.6	0.4	1.0	4.9

Table 4.2: Variations in Contact Intensity (after Goddard, 1975, p.46)

These findings, framed in terms of life-cycles and the earlier discussion of strong and weak ties, suggest that different stages in the production process require different degrees of contact with other firms and, thus, impose particular information costs on the management, planning, and control functions. This understanding helps to flesh out the division of the firm sketched out in Chapter 3 and why the 'information-intensive work' of planning, negotiating, designing, and consulting is so often firmly anchored in accessible urban areas: they are the sites where information can be actively and efficiently acquired.

Noise & Buzz (Passive Acquisition): Scanning entails a deliberate process of seeking out and exchanging information, but research by Storper and Venables (2002, 2004) into the 'buzz' of big cities opened up a new way of thinking about information acquisition that is closely connected to the earlier discussion of signalling[13]. The Silicon Valley region offers several well-known examples of buzz in action: the Homebrew hobbyist club at which Steve Jobs and Steven Wozniak premiered the first Apple computer functioned as both a job network and a kind of peripatetic trade fair, and alcohol lubricated the flow of information and ideas between engineers and entrepreneurs at Walker's Wagon Wheel bar in Mountain View (Hall, 1998, pp.443–454; Agmon and Von Glinow, 1991, p.107; and see also Figure 4.7). So the chatter that characterises the offices, studios, bars, and restaurants of big cities is actually a form of transmission, a "group-based self-generating exchange of information and knowledge outside [of] formal collaboration" (Asheim et al., 2007, p.658).

[13] See also Leamer and Storper (2001, p.649) for an early use of the term in a theoretical context. We would note too that the term was also being used in a similar way contemporaneously to refer to aspects of e-marketing and e-commerce with relevance to this discussion during the dot.com boom: see, for instance, Eakin (2001), Khermouch and Green (2001), Richter (1999), and White (1999).

The point is that buzz operates within a kind of 'ecology' created when people and firms in the same (or related) industries are in more or less constant social contact with each other (Bathelt et al., 2004, p.38). When participants are "surrounded by a concoction of rumours, impressions, recommendations, trade folklore and strategic misinformation" (Grabher, 2002, p.209), then the resulting swirl of information generates an almost unconscious awareness of who is working on what, who has landed a major new client, and who is tipped for a prestigious award. And while many of these exchanges may be social in nature, they nonetheless have important competitive effects and cement the reputations on which companies operating in opaque markets depend; for this reason, "part of the buzz of the city is judging, and putting oneself up to be judged" (Storper and Venables, 2002, p.25).

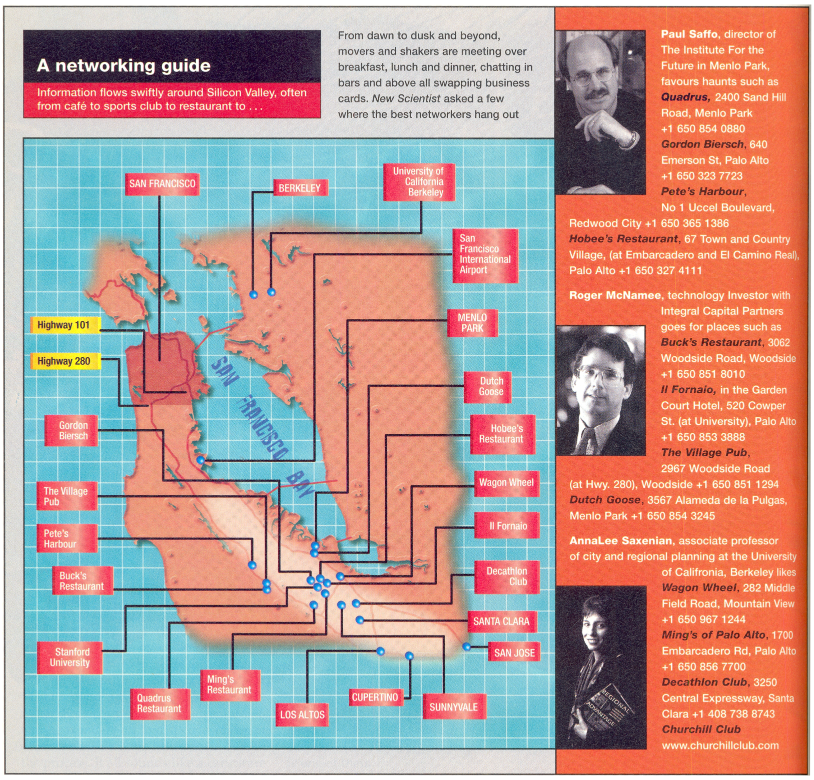


Figure 4.7: Silicon Valley Watering Holes (Mullins, 1998, p.34; reproduced with permission of the New Scientist)

Coherence & Diversity

The tension between strong and weak ties elaborated in this chapter can also be understood as the tension between coherence and diversity: it is a 'paradox of clusters' that if they lack any coherence then there are no synergies between firms, but that if they lack any diversity then they suffer from technological lock-in and a lack of long-term developmental resilience (Menzel and Fornahl, 2010, p.12). What I have sought to develop through the analysis of social networks is the idea that both coherence and diversity are essential to the proper functioning of a cluster. When combined with the spatial characteristics of social networks, this sets up a tension in which increasing distance—be it physical or metaphorical—increases the likelihood of diversity, but also reduces the likelihood of coherence.

In a similar way, Menzel and Fornahl (2010, p.8) base their definition of a cluster on the distinction between a thematic boundary that differentiates one 'production and innovation system' from others within its spatial range, and a spatial boundary that separates one group of organisations from others 'working in the same thematic field which are located elsewhere'. Firms that are in physical proximity to one another can bridge larger thematic distances, and so access more diverse sources of information (2010, p.26), while those with greater thematic coherence can collaborate effectively across larger distances. Menzel and Fornahl (2010, p.13) also suggest that 'size matters' because larger clusters can support more diversity than smaller ones can; and while they do not define exactly what is meant by 'size', we can infer that they mean the number of firms at the intersection of a thematic and spatial boundary and not the scale of production or number of employees.

I feel that this approach to clustering is particularly powerful because it accounts for the observed behaviours of firms in what are widely recognised as clusters, while also allowing for flexibility in the range of viable configurations that might qualify for this status. In that sense, Menzel and Fornahl (2010) move away from a deterministic or teleological account of clustering, and over time the tension between thematic and spatial coherence within a single cluster may even be expressed as a movement into entirely new technologies and an increase in heterogeneity (2010, pp.14–15). This is effectively what has happened in Silicon Valley, which has negotiated the transition through several generations of radical hardware and software change, and did not happen in Detroit, which once contained many start-ups pursuing a range of automobile technologies (2010, p.22).

Furthermore, by thinking about the process in this way, it becomes possible for two clusters—even ones of the *same* size and in the *same* industry—to contain different levels of diversity (Menzel and Fornahl, 2010, p.26). Even firms within the same cluster can pursue divergent or convergent technological or process strategies (2010, p.20). Cumulatively, these results take us further still from the idea that there is a pre-determined life-cycle for a cluster; instead, it is better to think of "a steady oscillation" (Menzel and Fornahl, 2010, p.15) between states of stability and growth. The ongoing tension between scale and diversity over the life-cycle of a cluster—together with the dynamics of renewal and decline—is brought together in Figure 4.8.

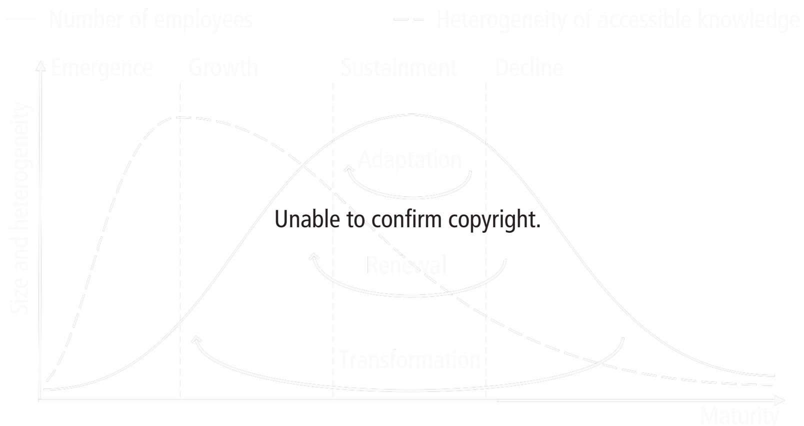


Figure 4.8: Quantitative and Qualitative Dimensions of the Cluster Life-Cycle (Menzel and Fornahl, 2010, p.14)

Technology

Studies of the creative sector might suggest that buzz is largely local (cf. Florida, 2002a,b), but Faulconbridge's findings (2007, p.1647)—together with the analysis of homogeneity above—have made it clear that the social networks that underpin buzz can also operate at much larger scales. Grabher (2001) explores one example of this process in action amongst employees in the different offices of a global advertising firm. By emphasising the role of spatial proximity and face-to-face interaction we may "unnecessarily fetishise the local" (Faulconbridge, 2007, p.1650) and overlook other mechanisms which may impact this process. For instance, Bathelt and Schuldt (2008, p.864) suggest that buzz can be created on a global scale through trade fairs, and there is growing evidence to suggest that it can also be generated and propagated electronically as well (Asheim et al., 2007, p.658).

The presumption in favour of F2F interaction being integral to buzz rests to some extent on the assumption that electronic communications cannot provide the kind of instantaneous group feedback that operates during, say, after-work drinks at a bar in New York. But as Jones et al. (2009, p.9) note, the emergence of collaborative, largely real-time platforms such as Facebook and Twitter may be enabling some privileged sites and technologies to become a vehicle for the broad-based, shared context that lies at the heart of buzz. I am obviously not suggesting that virtual proximity replaces physical proximity for social interaction, but to maintain that these interactions must remain uniquely local is equally improbable. Rather, what we seem to be seeing is an augmentation of both processes: as we communicate and travel more, the reach of buzz and, consequently, clustering is being significantly extended.

Spatial Implications

Returning now to the rise of 'boutique' consultancies, we can see how they illustrate the spatial implications of all of these different processes particularly well. Investment advisory services in particular have historically been a major source of income for the large commercial banks by dint of driving referrals to other parts of the business (Hall, 2007b, p.1840). We might expect that the large banks' brands would deliver an overwhelming advantage against small-scale market entrants; however, the niche focus and lack of complementary services has been taken by clients to mean that their advice will be more trustworthy and not part of a cross-sell or up-sell process.

The consultancies' founders also use their personal networks to recruit former colleagues as employees, and clients as sources of new business (Hall, 2007b, p.1847). Lacking the brand name of the white shoe firms, the boutiques—in common with other London-based SMEs (Keeble and Nachum, 2002, p.79)—employ their personal network as their principal business development tool. And while this strategy is available to small- and medium-sized firms anywhere in the country, firms in London are able to maintain more extensive networks more easily, and I believe that this helps to drive a pattern of development in which London-based SMEs not only seem to grow larger, they also appear to grow faster while generating higher levels of innovation (Keeble and Nachum, 2002, p.75).

Returning to the superlinear indicators listed on page 140 in the section on Agglomeration, we can see that the 'social' indicators can now be characterised network-driven externalities[14]. This effect can be demonstrated with social network models that focus on the interactions

[14] In a similar vein, Meier (1962, p.43) suggests that an "…intensification of *communication*, *knowledge* and *controls* [seems] to be highly correlated with the growth of cities," although his focus on formal information theory leads him to some slightly eccentric conclusions.

between a hierarchical social network (of the sort that might characterise a family or a firm) that encapsulates social distance, and a random interaction network (of the sort that might characterise the pattern of social interactions in a city) that encapsulates the 'bridging' component (Arbesman et al., 2009). Such a model generates superlinearity of the sort found by Bettencourt et al. (2007), and so one of the manifest benefits of large cities—in spite of the increasing costs of concentration such as congestion, crime, and so forth (Scott and Storper, 2003, p.584)—can be traced back uniquely to the opportunities for social interaction that occur there.

Summary

In examining clusters it is easy to focus on their spatial characteristics, but the problems of science cities and technology parks highlight the fact that proximity alone is not a guarantee of interaction, nor, thanks to telecommunications, is distance any longer a barrier to association. For instance, in Tsukuba, Japan, the hierarchical organisation of government laboratories inhibited researcher-led collaborations with the private sector (Castells and Hall, 1994, p.72). Conversely, in Sophia-Antipolis the MNEs showed little interest in cultivating an 'innovative milieu' (Castells and Hall, 1994, p.91), and Athey et al. (2007, p.5) have noted that in the Reading region "[local] networks, knowledge transfer and links are somewhat constrained by the corporate structure—as the innovation system tends to be dominated by large companies located in office campuses."

So while I have focussed in this chapter on the importance of personal social networks to clustering, we would also be wise to recognise the importance of institutions and their attitudes to networking as well (Torre, 2008, p.875). Of course, there is feedback between these two layers such that "the institutional form of an economy is, to some extent at least, a function of its social networks" (Green, 2001, p.19). What the approach taken here has shown is that proximity can be defined along several axes simultaneously, and that geographic distance on one axis may be less relevant if, for instance, shared employment or educational context creates closeness along another.

Linking this argument back to the earlier discussion of life-cycles also suggests that firms at different stages of development may perceive different benefits in clustering: 'young' firms (or firms in sectors where constant reinvention is the norm) may benefit from weak links and from highly-localised diversity (McCann et al., 2002, p.660)—which increases exposure to novelty—while more 'mature' clusters may tend to benefit more from strong ties and from systematic methods of knowledge acquisition—which improves efficiency (Staber, 2007, pp.510–511). Similarly, Asheim et al. (2007, p.666) have argued that the importance of 'buzz' diminishes in more mature industrial districts, and we can also expect that firms may concentrate more on intra-cluster relations during the early stages, and more on inter-cluster relations during later stages of growth (Torre, 2008, p.883).

And yet, some clusters seem to defy this life-cycle, or to preserve the characteristics of 'young' sectors indefinitely: speaking of the City of London in the 1950s and 60s, one interviewee comments that: "Everyone who mattered knew almost everyone else who did" (Kynaston, 2001, p.203). And in a discussion on the networking culture of Silicon Valley, Paul Saffo (director of the Institute for the Future) comments that: "Silicon Valley is a tightly packed place, hemmed in by hills on one side and water on the other—everyone is constantly tripping over each other, gossiping and swapping information and intrigue" (Mullins, 1998, p.33). It is this confluence of factors—geographic, social, and institutional (cf. Scott, 2000)—which suggests that clusters are rather more than, as Torre (2008, p.872) suggests, just the "'latest addition' to a long list of local production systems which assume that colocation is necessary for economic development."

4.5 Conclusions: Telecommunications, Agglomerations & Clusters

We began this chapter with the concept of the business life-cycle, and in spite of some important conceptual issues it proved nonetheless to be a useful short-hand for describing the mix of routine and non-routine activities at a firm, and how this mix changes over time. When paired with the concept of heterarchy, the life-cycle helps us to understand why the spatial concentration of firms alone can sometimes have so little impact on rates of innovation in office parks or science cities (Castells and Hall, 1994, p.81). Simply put, the kind of diversity that benefits firms in younger sectors—or, perhaps, young firms in established sectors—may not be compatible with the more managed, iterative innovation of large firms and MNEs. The former favour environments that maximise exposure to new ideas, while the latter favour coherence.

From the life-cycle, we turned to internal and external economies of scale, and found that the concept of an optimal size for the firm is complicated by the way that divisions may scale independently of one another as output increases. Consequently, I asserted the existence of multiple local optima for firms, and pointed also to the increasing costs of coordination and risk of failure as the firm ceases to operate as a coherent organism. Coordination costs affect firm location when, for instance, complex transactions require input from a wide variety of specialists; managing input from diverse groups can be effected via email in a series of round-robin communications, but it will often be far more effective to bring everyone together for a face-to-face meeting. So although they may be costly locations, major cities and sites near important infrastructure nonetheless offer high levels of accessibility and reduce the costs of coordination.

We next considered the changing nature of the labour market and the ways that cheap telecommunications and travel are impacting the distribution of companies: high-skill workers are able to access major labour markets from greater distances than ever before, but they nonetheless tend to participate in centralised labour markets. So although industries may want to avoid New York and London when their primary requirement is low-wage labour (Currid, 2007, p.47), when high-skill labour is required the situation can be very different. In fact, by some measures London's labour costs are apparently quite "low by world standards for the expertise available…" (Nachum, 1999, p.22).

This last point returns us to agglomeration, which we have treated primarily as a form of "large number search and matching system…" (Storper and Venables, 2002, p.38). The point is that within the model I have put forward, agglomerations are predominantly market-based and, implicitly, presume a degree of transparency; this does not mean that firms within agglomerations are necessarily engaged in direct competition—as Scott (2001) noted, many agglomerations have established narrowly-focussed niches that enable them to avoid competing with one another—but it does mean that there is less of a dependency on social mechanisms, which are the methods that continue to function effectively in opaque markets.

Ultimately, I have distinguished between clusters and agglomerations on the basis of the level of social interaction, but it should be clear from Figure 4.8 (page 156) that these two modes of operation are neither exclusive, nor easily distinguished. In fact, a group of thematically-coherent and spatially-constrained firms might easily oscillate between functioning as an agglomeration and as a cluster; depending on the circumstances, vertical and horizontal agglomerations could be a sign either of incipient clustering, or of post-clustering 'decay' (Menzel and Fornahl, 2010, p.23). Clusters can, therefore, be distinguished from agglomerations through their "unusual levels of embeddedness and social integration" (Hauser et al., 2007, p.78), even if it is, in practice, nearly impossible to quantify that process or to draw a neat line between the two types of industrial organisation.

However, it is also important that the value of embeddedness and social interaction is not available to all comers. Signalling and screening act to confine the circulation of information to a qualified in-group that have reciprocal relationships with one another. This is one very good reason for thinking that in some cases localised knowledge is perhaps better treated as a club good than a public good (Morrison, 2008, p.831). Workers in the City of London emphasised this dynamic through their habit of wearing 'the old school tie'—the ultimate in-group signal—on Fridays (Kynaston, 2001, p.213), but my additional claim is that the circumstances in which this type of mechanism is an asset are those were such signals are a way of building trust, and the links across which novel information can pass.

Coffey and Shearmur (2002, p.376) find that the most highly-clustered firms in the CBD are the high-order services that "generally involve uncertain data and ambiguity, decision-making, and lots of interaction between 'sender' and 'receiver' of information with qualitative-subjective features that are not easy to share via telecoms" (see also Figure 4.4 on page 139)[15], but the emergence of technologies that promise to recreate social processes similar to cluster dynamics in virtual contexts complicates this view.

Traxler and Luger (2000, p.286) asked if virtual clustering on digital telecommunications might eventually obviate the need for physical clustering? My answer is a qualified 'no', although the response will require expansion in the next, and final, theoretical chapter on the knowledge economy. My feeling is that the most socially-driven sectors—cultural, financial, etc.—will remain highly clustered even as their reach is extended by globalisation and technological processes that enable aspects of buzz and reputation to diffuse through virtual social networks as well as F2F ones. However, taken together, these factors suggest that true cluster dynamics affect only a minority of firms—in Soho and the City of London, for instance (Keeble and Nachum, 2002, p.71)—and that the colocation of ICT firms in Reading, for example, is more properly classified as an agglomeration. Testing this theory, however, will require access to the 'space of flows' and the ability to model the intensity of informational flows from firms according to both sector and geography, which we will tackle in Chapter 7.

[15] This is not to say that firms in opaque markets do not attempt to standardise practices and structures in search of efficiency and replicability: Faulconbridge (2007, p.1643) has noted that all of the advertising and law firms with which he spoke sought to capture and transfer 'best practices' through the use of "standardised client relationship management systems, financial management tools, and HR practices…"

5
The Knowledge Economy

5.1 Introduction

In the previous chapter we connected clusters to higher rates of innovation, and in this chapter we will examine in more detail the dynamics of knowledge generation (*who*) and circulation (*how*), together with the spatial implications for firms. The importance of understanding and defining this type of work arises because enormous incentives from local and national governments are riding on complex sets of assumptions about knowledge: for instance, if innovation is localised and stochastic—*i. e.* random in the way that the weak ties model asserts—then communication within and between firms is vital to capturing and exploiting opportunities. But if innovation can now be 'programmed' in some more deterministic way then regional development authorities can and should offer innovative firms the physical and social infrastructure necessary to succeed.

However, an interest in knowledge workers and innovation is not new, and Lösch wrote of factors or production that were 'exhaustible, immobile, or unique' and ranked among them "gifted men who refuse to migrate" (1954 [1973], p.23). The human dimension is important: it is easy to forget that real knowledge flows happen between people, not firms (Torre, 2008, p.877), and that they "remain the containers for shipping complex uncodifiable information" (Leamer and Storper, 2001, p.648). We will consider what 'uncodifiable' means in a moment, but for now let us recognise that the human aspect of knowledge places innovation issues squarely within the realm of the social. Consequently, technologies that impact our social networks and their distribution in space seem likely to have a profound impact on the nature of knowledge work, much as they do on clustering. Global knowledge access would also imply a radical globalisation of the geography of innovation: might firms then turn to Asia for 'cheap smarts' in the same way that they turn there now for cheap labour (Brinkley, 2006, p.10)?

5.2 The Production of Knowledge

Formal Definition

In the three previous chapters I have tended to use the terms 'data' and 'information' interchangeably, while attempting to avoid introducing the notion of knowledge even though, quite obviously, not all intangible goods and services exchanged between individuals or firms consist only of data. We understand intuitively that knowledge is somehow 'different' from mere facts since it connotes discernment or judgement in a way that simply reciting details or measurements does not. Drucker (1999, p.126) suggests that "information is organised data", while Economist (2010a) suggest that: "Information is made of a collection of data; knowledge is made of different strands of information."

One pragmatic way of looking at this issue is to return to our ongoing consideration of the financial markets. The fact that company XYZ's stock is trading at $75 a share is simply a data point with little innate action value: is that a good price, or a bad one? The fact that company XYZ's stock has risen by $20 in the past two months gives this datum a *context*: we now know that this represents a 36% return-on-investment (ROI). But it is only when drawn together with other strands of information—the performance of XYZ's peer group, the marketplace, and the regulatory environment—that this starts to become knowledge predicated upon the weighing of factors. While information is essentially passive, 'knowledge empowers actors with the capacity to act' (Brinkley et al., 2009, p.11).

For Echeverri-Carroll et al. (2007), knowledge belongs to a 'community of practice' which might encompass engineers who meet at a bar to talk shop, and parents who meet in a café to share stories of raising children; and it also implies the existence of an 'epistemic community' that is rooted in professional networks with an 'authoritative claim to expertise in a particular domain' (2007, pp.715–716). Particularly in the latter case, the members of these communities may be quite physically distant from one another but nonetheless adhere to a common set of 'beliefs' in a particular area (Grabher, 2004, p.110). The set of norms defines how issues are understood, discussed, and acted upon since "[learning] is not simply a matter of acquiring information: it requires the development of a disposition, demeanour, and outlook of practitioners" (Echeverri-Carroll et al., 2007, p.715).

The 'climate-gate' e-mail controversy is a useful illustration of this point since it marks the collision of two distinct communities: one a community of climate researchers based largely at East Anglia, the other a more diffuse one rooted in doubt about the very existence of climate change. The epistemic dimension is particularly clear here: scientists opposed the release of data to sceptics on the grounds that they "would not understand them" (Pearce, 2010) and encouraged colleagues to delete email subject to Freedom of Information (FOI) requests so as not to cast doubt on their results (Randerson, 2010). Fundamentally, this is an argument about legitimacy, and the scientists felt that the sceptics had neither the background, nor the expertise to evaluate the data appropriately and derive new knowledge from it.

Tacit & Codified Knowledge

This controversy should help us to see how the distinction between information and knowledge is caught up in the idea that some types of knowledge are *codifiable* while others are not. For instance, the methods underpinning climate change research can be easily posted online, as can the outputs of the models, but the expertise required to judge which method to apply, what adjustments might be needed, and the reliability of the results cannot. Quite simply: codified knowledge can be fully *encoded* in some replicable way while its complement—tacit knowledge—cannot.

Codified knowledge therefore has a "stable meaning which is associated in a determinate way with the symbol system in which it is expressed, whether it be linguistic, mathematical, or visual" (Storper and Venables, 2004, p.353). The critical point is that while acquiring the 'symbol system' and building a means to transmit encode-able knowledge may be expensive, subsequent communication can be easy (2002, p.18). In economic parlance, codified knowledge has strong 'network externalities' (2004, p.354) in that it can continue to be acquired without direct, ongoing social interaction (Cook et al., 2007, p.1327).

In contrast, tacit knowledge defies a straightforward encoding—it is profoundly 'analogue'—and often "requires a kind of parallel processing of the complexities of an issue, as different dimensions of a problem are perceived and understood only in relation to one another" (Storper and Venables, 2002, p.19). The relational component is both analytical—seeing the implicit connections between issues—and literal—forming this knowledge through interaction with other experts. Tacit knowledge is therefore presumed to be profoundly context-dependent and we can think of it as existing, or being produced, in the moment of transmission (Cook et al., 2007, pp.1327–1328). It is the 'you should have been there' experience and builds on our social awareness of others: their tone of voice, their physical and emotional disposition, and their level of engagement with the task at hand; because of this there are few network externalities.

Software development offers a particularly good example of the difference between codified and tacit knowledge: no matter how arcane, programming languages are still constrained by the requirement that they translate some process into a set of logical operations. So while the exact function of a line of code may take time to work out, it is ultimately accessible to anyone who invests sufficient time and effort in learning the underlying language[1]. The formal rules of computer languages are what make bulletin boards and discussion groups such an effective method for dispensing advice, but the broader implication is that for this type of knowledge there is a growing stock of ideas that can be accessed globally (Brinkley, 2006, p.10).

[1] This is not to suggest that there are not cultural and stylistic norms within programming subcultures—including *Leet/l337*-speak—but these are simply acquired norms of expression and do not fundamentally impact another developer's ability to understand the function of a script or application if given enough time to work through the code.

In contrast, tacit knowledge remains 'geographically sticky' because it is formed within a particular social context; it is therefore accessible only through relations that are "not simply…input-output relations or linkages, but [are] untraded interdependencies subject to a high degree of reflexivity" (Storper, 1995, p.4; see also Staber, 2007, p.509). Because it is not widely available, tacit knowledge creates a key competitive advantage for firms that are able to access and exploit it; or as Mitchelson and Wheeler (1994, p.87) put it: "the success enjoyed by New York firms is not, of course, independent of their location amid the greatest volume of nonroutine information ever assembled in one place."

The distinction between tacit and codifiable knowledge therefore maps surprisingly cleanly on to the distinction—first raised in Chapter 3—between information as a locational input with high shipping costs, and information as a ubiquitous resource. Of course, a good deal of knowledge will sit somewhere between these poles; this only implies that the locational effect of knowledge will vary in proportion to its codifiability. For firms, especially MNEs with dispersed operations, the ability to transfer knowledge between offices is an important competitive advantage, so they will have strong incentives to identify and exploit ways of codifying complex, formerly tacit knowledge (Morrison, 2008, p.827).

How might this codification occur? Successful approaches might include the use of standardised analysis tools or processes, training seminars, and social functions that encourage the mixing of, and sharing between, staff. In fact, the rise of video conferencing and Internet/Intranet-based forums (*e.g.* Wikis, Groupware, etc.) within corporations suggests that firms are already hard at work on ways to circumvent the spatial constraints of tacit knowledge through the judicious application of technology and exploitation of managed external linkages.

Knowledge Bases

The dichotomy between codified and tacit knowledge can be complemented by Asheim et al.'s argument (2007) that there are three different classes of knowledge: analytical, synthetic, and symbolic. In many ways, analytical knowledge is most closely connected to codifiable knowledge, while synthetic knowledge is presumed to be generated iteratively and transmitted bilaterally, making it similar in operation to tacit knowledge. The concept of symbolic knowledge relates to undirected, multilateral interaction and so brings us back to the concept of buzz explored in Chapter 4 (page 154), seemingly creating a third axis of transmission along which knowledge can propagate.

ANALYTICAL: The analytical knowledge base is oriented towards what we commonly understand as scientific knowledge; these are fundamental principles in nature and society that are testable or falsifiable and, generally speaking, replicable. This type of knowledge can be elegantly summarised as 'know-why', and it often requires "analytical skills, abstraction, theory building, and testing" (Asheim et al., 2007, p.661). Because scientific knowledge is typically encoded in formal symbol systems (*e.g.* mathematics) it can often be made available to others by publication, and as a result it may require little in the way of face-to-face interaction in order to propagate effectively (2007, p.662), nor does group interaction seem to be essential to the pursuit of analytical knowledge.

This configuration would seem to reduce the need for proximity, and from this definition it is clear that analytical knowledge comes from two main sources: academic institutions and private entrepreneurs. Commercialisation pressures on universities, and resource constraints on firms, mean that both may have a strong interest in some types of research collaboration. The increasing codependence between these two groups creates an incentive for analytically-based industries to locate in the general vicinity of "major universities or research institutes carrying out leading research in their field" (2007, p.662). The key here is that availability and accessibility are not the same as a requirement for permanent 'copresence', so this type of innovation 'milieu' might operate across a wider geography so long as the travel requirements remain modest. Moreover, the codifiability of analytical knowledge suggests that firms may be able to transfer it across long distances.

Synthetic: Synthetic knowledge is created in response to specific issues, often in an iterative or evolutionary manner. Regardless of the 'sophistication' of the field, synthetic innovation arises from 'know-how' rooted in experience and long-term relationships between clients and suppliers pursuing what is often called 'applied research' or 'product/process development' (Asheim et al., 2007, p.663). So synthetic knowledge is not associated with many-to-many interactions, and although synthetic outputs must be codifiable to some extent (*e.g.* as blueprints), many of the inputs will remain profoundly tacit because they flow from what is "often a trial-and-error process, involving user-producer interaction as an essential input and selection mechanism for innovation" (2007, p.663). The specificity of solutions derived from synthetic knowledge may make it difficult to generalise a solution.

Examples of synthetic innovation and knowledge at work include: plant engineering, advanced industrial machinery, production systems, and shipbuilding (*ibid.*). Architecture, however, is a particularly interesting example since each 'solution' is unique, but broader generalisations are also possible (cf. Rybczynski, 1990). In all of these cases there is obviously a strong connection between synthetic knowledge and iterative innovation ((Asheim et al., 2007, p.657); see also Moodysson et al., 2008, p.1044). Iteration implies that the cost of meeting will recur regularly even if telecommunications can be used to manage more mundane issues. As a result, we would expect to see the firms "agglomerate in traditional clusters to exploit the advantages of being close to suppliers and customers" (Asheim et al., 2007, p.663); however, this agglomeration does not *need* to be in an urban area because the emphasis is on bilateral, rather than multilateral, relationships. Consequently, the cost and accessibility benefits of a suburban location may trump those of more central sites.

Symbolic: Symbolic knowledge arises from "the creation of cultural meaning through transmission in an affecting sensuous medium" (Asheim et al., 2007, p.661). This knowledge is, in other words, primarily artistic and aesthetic in nature, incorporating everything from industrial and graphic design, to advertising and filmmaking, as well as art and music. Generally speaking, we are dealing here with cultural and craft outputs across a range of material and immaterial media, and clearly these products also have a very strong tacit component (Asheim et al., 2007, p.664), but one that is rooted in the complex associations, aspirations, and connotations that particular brands, artists, and performances raise for each of us.

We would expect a great deal of interaction to be involved in symbolic knowledge generation since output in these sectors is often rooted in collaborative project-based work that draws on a range of disciplines. For instance, a young fine art photographer and an established fashion designer may work together on a t-shirt featuring some of the photographer's more controversial work (cf. Helmore, 2010). Symbolic work tends to involves a great deal of feedback, with producers of one cultural product often being consumers of another: there is an importance to what music the designers hear, and to what clothing the band wears (Currid, 2007, p.7). Because of its cross-cutting nature, knowledge about the market and the roles of individuals within it is often generated at large gatherings (Asheim et al., 2007, p.665), and this places the effects of buzz—outlined in Chapter 4 on page 154—squarely within the productive process of the symbolic base; it also connects symbolic output to a propensity to cluster.

The rate of change in cultural outputs also means that, in spite of the money at stake, the selection and implementation processes remain profoundly subjective and contextual. Moreover, the majority of aptitudes required for symbolic innovation are not 'teachable' in formal situations and so qualifications and degrees mean relatively little. In fact, one well-known author has gone so far as to argue that creative writing degrees from universities may well be an indicator of *unsuitability* for the profession of writer (Menand, 2009). In the absence of objective metrics, buzz is essential for knowing "who is relevant, available, and interested in participating in a particular project" (Asheim et al., 2007, p.665). So what is being communicated in social contexts is not only the 'know-how' of artisanal output via 'learning by doing', but also the 'know-who' of who is suitable for a project (Asheim et al., 2007, pp.664–665). For this process to operate effectively, participants must be able to interact with one another on a frequent basis, and the only place where intensive, regular multilateral flows are cost-effective is the city.

Summary: Of course, although we have discussed each knowledge base in isolation, it is clear that there is the potential for significant levels of overlap between them. Moodysson et al. (2008) examine two life sciences projects in Sweden, finding that in one case two separate analytical breakthroughs were merged into a commercial, synthetic project (2008, pp.1047–1050), while in the other case study two firms engaged in an intense synthetic collaboration around a new product that eventually resulted in a patentable—which is to say, analytical—output (2008, pp.1050–1051). The point here is that, over the life-cycle of a product, we may expect the manner of working and problem-solving to shift—perhaps frequently—between bases. With this important qualification in mind, the broad differences between the three knowledge bases are summarised below in Table 5.1.

Analytical	Synthetic	Symbolic
Innovation by creation of new knowledge	Innovation by application of novel combination of existing knowledge	Innovation by recombination of existing knowledge in new ways
Importance of scientific knowledge often based on deductive processes and formal models	Importance of applied, problem-related, knowledge (engineering), often through inductive processes	Importance of reusing or challenging existing conventions
Research collaboration between firms and research organisations	Interactive learning with clients and suppliers	Learning through interaction in the professional community, learning from youth/street culture or 'fine culture, and interaction with 'border' professional communities
Dominance of codified knowledge due to documentation in patents and publications	Dominance of tacit knowledge due to more concrete know-how, craft, and practical skill	Reliance on tacit knowledge, craft, and practical skills and search skills.

Table 5.1: Summary of Knowledge Bases Approach (Asheim et al., 2007, p.661)

Technology

As Leamer and Storper (2001, p.651) and Storper and Venables (2002, p.20) note, there is a parallel between codifiability and the 'searchability' of goods that we considered in Chapter 3 (see page 99). Codifiable knowledge, like a search good, has qualities that can be objectively assessed from afar, while tacit knowledge, much like an experience good, has qualities that are only available through prolonged involvement in its production or consumption. As a result, we may expect the same spatial relationships to generally hold true: that codifiable knowledge will be increasingly easy to seek out and source from anywhere in the world, while the search and implementation costs of tacit knowledge will continue to place a premium on proximity for the sake of efficiency and accessibility.

However, for Echeverri-Carroll et al. (2007, p.715), the key to the knowledge economy is not so much gaining access to information as developing new ways of 'working with, and working together with' it. The proliferation of information online has made it increasingly necessary—at least in technical circles—to think about metadata: information about information (Economist, 2010d). In a sense, metadata is a way not only of working with data, but also of building new knowledge around it; in this there is an important link back to Lösch's (1954 [1973]) discussion of finished and unfinished goods (see page 44). Here, raw data is the unfinished good, while metadata and relationships that it captures between data are the finished product.

Card catalogues and bar codes are both examples of early metadata (Economist, 2010d), but its role has expanded enormously with the growth of digital storage and retrieval. In effect, Google's $180 billion business *is* metadata, but the current 'revolution in search' shows just one way in which increasingly complex information—types that might once have been considered tacit knowledge—can be codified and categorised by machines, or by machines and humans working together. In short, investment in better ICT is enabling firms to move the boundary between tacit and codified knowledge in their favour.

Torre (2008, p.870) goes further than this, arguing that ICTs make 'long-distance sharing or coproduction of tacit knowledge possible'. Anecdotal evidence of this is beginning to emerge, with online interaction even being employed in the production of animated, feature-length Hollywood productions (Brody, 2009; Crockett, 2007). The key is that high-bandwidth applications such as Skype and Apple's iChat now offer a way for colleagues at geographically distant sites to collaborate by voice, video, and screen-sharing, all at once. Since peer-to-peer calls are entirely free, it should hardly be surprising that Skype's cross-border traffic increased by 41% in 2008 alone, but it transpires that Skype is already the world's largest cross-border telecommunications carrier, full stop (TeleGeography, 2009). AT&T spent millions of dollars in the 1960s developing the 'videophone', only to abandon it as a commercial non-starter; but in the space of just a few years—thanks to the increasing integration of networks, computers, and cameras—it has become commonplace.

The videophone illustrates several socio-technical and economic dynamics rather well. First, in line with 'Metcalf's Law', the value of one videophone is effectively nil since there is no one with whom to use it. Second, the poor quality of video did not pass as a substitute for F2F interaction at a time when, since people travelled less, their need to maintain extended social circles was lower. So the success of Skype and other forms of video chat is a function not only of the reduced cost of cameras (many laptops now come with them built-in), and of the increased rates of travel and migration (people use the 'personal touch' of video to maintain extended networks), but also of the massive increase in accessibility brought about by the spread of public WiFi hotspots. So it is not so much that the videophone was the wrong concept, but that the lack of integration and immediate demand made it very much the wrong time.

Summary

In line with Brinkley et al. (2009, p.11), I have proposed in this section that telecoms are making data, information, and codified knowledge largely indistinguishable. When we encode an idea, process, or interaction, we can now transmit it to another point on the planet nearly instantaneously. And the 'informational exhaust' of these operations becomes itself the input to new rounds of innovation in products and services: for instance, the Chinese logistics firm Li & Fung substituted video conferencing where, historically, samples had been sent in the post to clients for quality-control processes; however, the firm quickly realised that the resulting data flows could also be used to identify changes in the geography of sourcing and in overall retailing trends months before these showed up in more traditional data sources (Economist, 2010b).

Clearly, the arrival of high-bandwidth digital networks represents an enormous scaling up of the externalities associated with codified knowledge. Historically, delays in transmission and limits on the amount of data that could be collected, analysed, and relayed would have placed important constraints on the use, and re-use, of information. Now, suppliers to Wal-Mart can not only see how well their products are selling generally, but also how well they are selling on a store-by-store basis and with what *other* products their wares are being purchased in real-time (Economist, 2010b). Google has experimented with mapping web searches for flu symptoms as a way of predicting the spread of the virus, and has found that its results are about two weeks ahead of hospital-collected data from the Centre for Disease Control, and they are nearly as accurate geographically (Google, 2010).

The proliferation of ubiquitous information, together with the rise in distributed knowledge generation by multinationals, is also creating demand for an entirely new discipline: knowledge management. A survey of firms by Brinkley (2006, p.28) found that twice as many managers expected knowledge management to be the biggest source of productivity gain as chose new product development or supply chain management. This finding may reflect the heavy optimisation of these other aspects of firm operation, but it is nonetheless a remarkable transformation for firms to see the storage and dissemination of knowledge itself as the critical source of future competitive advantage for their business rather than the more 'traditional' areas of business optimisation.

Yet if access to codified knowledge becomes easier, then the ability to produce and control tacit knowledge paradoxically becomes more important to the firm. This will be true not only in the commercial sense but also in terms of the locational decisions that the firm takes in order to secure access to this type of knowledge. Torre (2008, p.873) suggests that we should view *all* types of knowledge as 'imperfectly appropriable', and that proximity simply lowers the barriers to access and enables firms to benefit from spillovers more easily; this would certainly fit with the previous chapter's conclusions.

What the knowledge bases approach enables us to grasp is *why* these spillovers appear to operate differently depending on the sector: the nature of symbolic knowledge requires the copresence of large, diverse groups of socially connected people in a metropolis, whereas analytical knowledge can arise amongst people in relatively more remote locations such as small university towns. Of course, in practice scientists will

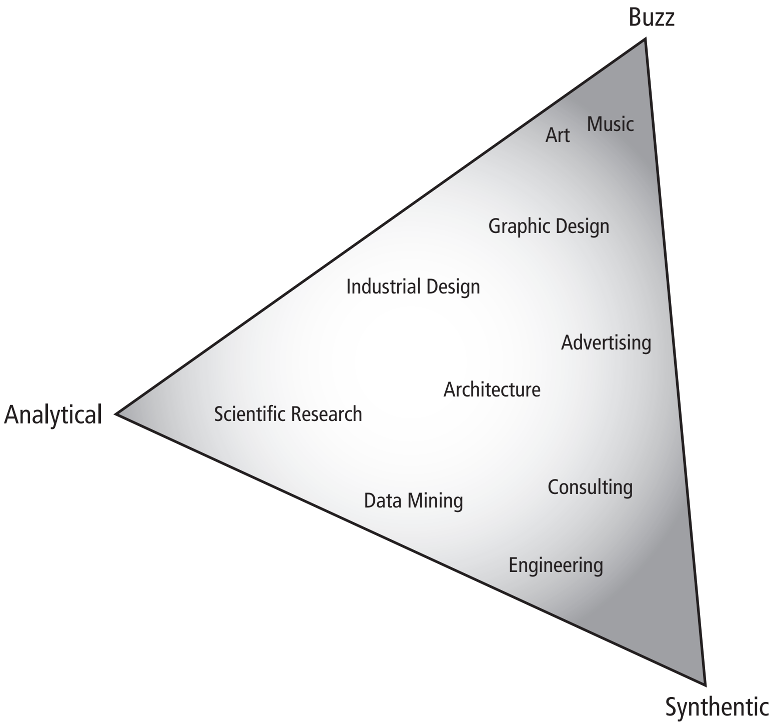


Figure 5.1: Typologies of Knowledge

make use of buzz about who is working on ground-breaking research, and advertisers will make use of synthetic knowledge built up over the course of a client relationship to deliver creative solutions that meet their clients' needs. In Figure 5.1 I have deliberately done away with the sharp distinctions between the bases to highlight how most professions contain mixes of all three. The figure is necessarily impressionistic, but what it communicates is consistent with our findings so far, and it serves to emphasise the fact that firms must strive to balance these potentially conflicting knowledge-generation needs—and their associated spatial interaction requirements—when making locational decisions.

How does this three-sided figure fit with the earlier exploration of codified and tacit knowledge? Rather than squeezing one model into the other, I would suggest that it is more helpful to see codification as being orthogonal to this plane, meaning that all bases are to some extent codifiable and, simultaneously, that all are to some extent tacit. The epistemic community bridges the two approaches: even were knowledge 'floating freely', the receivers would still need a shared 'cognitive framework' with the transmitter in order "to make sense and value of this knowledge" (Moodysson et al., 2008, p.1054). The community of expertise enables scientists to have a tacit understanding of 'how science is done'—in their lab, at their institution, as a global community of researchers—and enables engineers to codify the output of a client's needs in the form of blueprints or lines of code. In short, these views of how knowledge is created complement each other, enabling us to turn to how new knowledge may be shared with others.

5.3 The Exchange of Knowledge

In his review of the literature, McCann (2007, pp.118–119) notes that most economic models presume that knowledge flows are predominantly local, and that these short-range exchanges lie at the root of innovation. But as Clark and Thrift (2003, p.17) have pointed out, this comes at a time when collaborating individuals and organisations are increasingly dispersed geographically. So how do we reconcile these seemingly contradictory trends? This part of the thesis seeks to shed additional light on the argument, developed in Chapter 4, for why proximity is important for firms involved in innovative outputs (Dawkins, 2003, p.141), but we will also see that firms are increasingly able to supplement physical proximity with engineered forms of proximity.

Face-to-Face Interaction

As our examination of tacit knowledge and of the synthetic and symbolic knowledge bases makes clear, particularly complex forms of (new) knowledge seem to be best communicated in person. We can trace the roots of this idea in planning and economics literature back through seminal work by Storper and Venables (2002, 2004) to more purely information theorists such as Meier (1962), all of whom argued that F2F interaction should be treated as a communications technology. This idea builds on the fact that inter-personal interaction is clearly not just about what is said or seen: Storper and Venables (2002, p.14) and Boden and Molotch (2004, p.103) point out that we extract information in social contexts from the verbal (*what was said or unsaid?*), the physical (*was there physical contact? where? for how long?*), the contextual (*where did we meet? who was at the meeting?*), the intentional (*what have the attendees done to bring this meeting to fruition*), and the unintentional (*what does their demeanour indicate about their level of commitment?*).

To put it another way, as profoundly social animals we engage with, and respond to social stimuli in ways that we would never respond to a written report, a phone call, or an email. Copresence is 'like being on stage and playing a role' (Storper and Venables, 2004, p.355): sometimes it is the performance, not the message, that plays the pivotal role in effective communication. In person, the host of a meeting can much more easily see that he or she is 'losing' the audience and adjust the delivery of their message accordingly (2004, p.354). Readers have undoubtedly all experienced the crucial project meeting or presentation from which the participants emerge more motivated—'fired up'—physically and psychologically than they were when they entered the room.

We can think of this engagement of all five senses as delivering truly staggering bandwidth—Meier (1962, p.64) estimated that it would take 3–10 times as much interaction over the phone to achieve the same 'channel capacity' as a face-to-face meeting—and enabling the processing of information "not only deductively but analogically, metaphorically, and through mutually-enriched parallel methods [as well]" (Storper and Venables, 2004, p.355). As a result, 'instrumental assumptions'

Function	Context	Effects	Outcomes
Communication technology	Non-codifiable information	High frequency	Efficient communication under uncertainty, especially of tacit knowledge
	Teaching	Visual and body language clues	Acting or responding correctly under uncertainty when a message is intended
	R&D	Rapid feedback	
		Parallel sending and receiving of information	
Trust and incentives in relationships	Meeting	Co-presence and commitment of time as 'forfeitable bond'	Ability to trust and bond where messages and their content are inherently uncertain
		Detection of lying	
Screening and socialising	Professional group	Loss of anonymity	First-mover advantages in innovation and learning
	Being 'in the loop'	Judging and being judged	
		Acquisition of shared values	
Rush and motivation	Presentation	Performance as display	Productivity, creativity, inventiveness & energy

Table 5.2: Face-to-Face Interaction (after Storper and Venables 2004, p.353 and 2002, p.15)

that sending more data down a wire will somehow substitute for F2F interaction are naïve (Graham, 2004, p.101), and the issue for remote collaborators is therefore that creative problem-solving simply does not seem to function as effectively over the wire.

The wide range of potential benefits embodied in F2F interaction is summarised in Table 5.2; but one of the more subtle benefits is the way that "the face-to-face encounter presents a much fuller opportunity to develop deep commitment and trust…" (Graham, 2004, p.101). So while the effectiveness of a meeting derives in part from the bandwidth of F2F interaction, it also derives from the signal it sends that participants have made a real investment to attend (see Information Acquisition on page 150 for a fuller discussion). Or as Boden and Molotch (2004, p.103) put it: "copresence requires participants to set aside not only a shared time but a shared space, while also constraining other activities that can take place." In short, meetings help to weed out the partners who are "unable or unwilling to put in sufficient effort to bring a collaboration or project to fruition" (Storper and Venables, 2002, pp.30–31).

Even if professional and social 'screening networks' can be maintained electronically (something we will consider in more depth on page 177), it should also be clear that periodic F2F helps to raise barriers to entry by 'producing a loss of anonymity and exposing individuals to the judgement of peers' (2004, p.356). As I emphasised in the section on clustering, this evaluative dimension is crucial in opaque markets and F2F streamlines this process by making it easier to create and maintain groups (Meier, 1962, p.42), as well as faster to arrive at 'complex judgements of character and trustworthiness'. The implicit cost of

F2F meetings is therefore particularly important when the returns are substantial but the risk of 'freeloading'—because of opacity—is high (Storper and Venables, 2002, p.21).

Writing about the importance of such networks in the operations of the City of London in the 1960s, Kynaston (2001, p.205) notes that "it was all about picking the right people—definitely an art rather than a science…" And on an empirical level, financiers interviewed more recently by Cook et al. (2004, pp.18–19) reported that the ability to meet in person reduced the risk of a costly misunderstanding and enabled information to be communicated more quickly (Cook et al., 2007, p.1334). The respondents also noted that it could be difficult enough to get employees of the same firm in different offices to collaborate and communicate effectively, and that the challenges are even greater when employees from different firms or industries were involved.

While many interactions—such as meetings—are structured so as to be both formal and informative, we shouldn't discount the role of the 'ritual and communal' in such communications as well (Graham, 2005, p.99). Thus frequent and intense communications support the emergence of a 'common culture' (Cook et al., 2004, p.21), and enable fruitful interactions between clients, competitors, and even regulators (2007, p.1336). Where this culture is spatially, as well as socially, constrained, then it will produce a locational asset that is difficult to replicate (Taylor et al., 2002, pp.93–94).

Valuing Physical Proximity: A slightly different approach to F2F was adopted by Leamer and Storper (2001), who divide personal interaction into two categories: handshakes and conversations. Handshakes establish the context for future conversations by cementing a mutual understanding of the goals and abilities of the participants, while conversations are connected to the ongoing flow of information between collaborators. More concretely, we can think in terms of a project: there is nearly always a 'kick-off' meeting in which the collaborating teams meet each other, introduce themselves, socialise, and agree how interactions will occur in the future; however, following this crucial first encounter the project typically settles into a more 'routine' format where information is exchanged and participants are updated on the progress of various tasks.

We can formalise the spatial implications of this analysis using a framework proposed by Charlot and Duranton (2006, pp.1368–1370). Recall that in Chapter 3 (see page 99) we considered how the costs of a transaction are spread across search and implementation phases. Implicit in this model is the question of whether coordination during each of these phases can benefit from F2F encounters, and how costly these meetings are to their participants. If the coordination tasks are straightforward, then they will usually be performed electronically (*e.g.* by phone, email) because that is the fastest *and* the cheapest way to do so (Charlot and Duranton, 2006, p.1369). But if the coordination required is complex, or entails iterative problem-solving or tacit knowledge then, on balance, it would be more suitable to resolve it through a costly

F2F meeting. Interestingly, this model brings us full-circle to the form of consumption discussion in the review of Lösch (see page 44) and connects it to the idea of a threshold of complexity for informational transactions.

So we now have a threshold of complexity and value: below this boundary coordination takes place via telecommunications, and above it a F2F meeting is required. What Charlot and Duranton (2006, p.1370) point out, however, is that the costs of a meeting are higher in a city—because of travel, rent, congestion, and labour costs *inter alia*—than they are in suburban or rural area and that these costs increase with the size of the city while the cost of telecommunications remains the same. Consequently, the threshold of a 'complex' problem increases with the cost of the location (*ibid.*). But what cities take away in terms of cost, they return through the increased probability of finding a suitable partner: more firms are accessible and the odds of a match within a fairly short range are higher (2006, p.1371). Meier (1962, pp.64–65) notes that many business meetings to organise a project will go nowhere, but that when they succeed then a skyline or a market can be transformed; we can now see why these types of transformative projects are often uniquely urban in nature.

However, this approach says little about how the trade-offs vary across sectors, and McCann (2007) points out that not only do we typically assume that F2F has the same value to all firms, but also that all firms have the same required frequency of interaction. If we allow the demand for F2F to vary by industry, then we can see how firms with complex needs will have very high travel costs indeed if they must journey some distance in order to meet with suppliers, clients, or partners (2007, p.122). Comparing the F2F needs of people in advisory or deal-making roles with those of innovators, Buck et al. (2002, p.119) argue that the latter "have [an] insufficient need for F2F contact to justify London rents" and we can see how this need is rooted in part in the difference between, say, 1–2 meetings per week and 1–2 meetings per day.

In sum, the greatest benefits of physical proximity will accrue to individuals and firms that have complex outputs, short product cycles, frequent contact needs, and a predominance of short-term contracts (McCann, 2007, p.131). This result connects the economic cost of travel (*e.g.* for meetings) to the distribution of sectors within the city-region: sectors employing symbolic or synthetic knowledge—such as finance, publishing, consulting, and the arts—with frequent interaction requirements will normally be willing to outbid those sectors—such as R&D or engineering—with less of a need for F2F and, consequently, a diminished dependency on central locations (2007, see footnote on p.132).

Other Proximities

Temporary Proximity: The growth of mobility and ICT-enabled interactions means that permanent proximity may no longer be the only way to exchange complex knowledge. The simplest way to offer propinquity without colocation is travel. Grabher (2002, p.210) and Torre (2008, p.879) suggest that technology has increased our ability to coordinate activity to the point where some collaborators now only need to meet intermittently. And as we have seen, proximity will tend to be important at the beginning of a longer-term interaction: it is the point at which the rules and codes for a subsequent interaction are implicitly and explicitly negotiated (Torre, 2008, p.884). In other words, temporary proximity can function effectively during the 'handshake' phase of a transaction.

So where ongoing F2F needs are modest, employees can be moved on-site while they 'ramp up' and get acquainted with their new colleagues. They then return to their 'home' office with both codified and tacit knowledge about the way that 'things are done' within an organisation and as carriers of a corporate culture. In short, temporary proximity, supported by global and regional transportation systems, offers firms a new level of locational flexibility by reducing their immediate dependence on F2F. Obviously, this type of interaction could also be generated at trade fairs and conferences which 'compress an entire world into a single place' (Rychen and Zimmermann, 2008, p.774)—and also seem to display some of the benefits of a cluster in terms of monitoring (Morrison, 2008, p.826), building buzz (Rychen and Zimmermann, 2008, p.774), and identifying new opportunities (Cole, 2008, p.896).

Virtual Proximity: An alternative to temporary copresence is telepresence, and a good deal of work is now done from remote locations via a variety of services: voice, video, email, and web, to name just a few. Given the focus in this chapter on how F2F interaction is integral to tacit knowledge transfer and complex problem-solving, we might expect telecommuting to be associated with less-skilled positions. But while this appears to the case for some areas such as telesales, most data on teleworking suggests that it is dominated by those with a college education performing highly-skilled tasks (Haddon and Brynin, 2005, p.40).

This seeming contradiction is driven by the fact that many ostensibly home-based teleworkers seem to work only part-time from home (Haddon and Brynin, 2005, p.36). In fact, the number of hours spent by telecommuters on 'telework' may not be all that great (2005, p.39), and full-time remote working seems to produce a sense of isolation, leading to a loss of creativity as well as a feeling 'economic precariousness' because the employee is no longer fully-integrated with the firm (Traxler and Luger, 2000, p.290). And, reinforcing the earlier point about handshakes and conversations, Echeverri-Carroll et al. (2007, p.715) note that 'virtual teams' often need an opportunity to develop or reinforce relationships through F2F interaction so that they can collaborate effectively.

Until recently, the more expensive forms of telepresence were largely a tool for executives already at the limits of travel endurance; this way they could tack on one more meeting without needing to tack on another plane trip (Crockett, 2007; Economist, 2007a, 2009b). By implication, this type of telepresence is a substitute for face-to-face interaction only when absolutely necessary, and it is not a first-choice. Evidence from 'high touch' sectors such as venture capital (VC) indicates that it is the firms with the most F2F interactions that *also* use telecommunications most actively (Fritsch and Schilder, 2008, p.2125). Recall too that Figure 1.2 in the Introduction (see page 22) shows telecoms usage and business travel increasing in parallel. The point is that copresence seems set to remain an essential component of knowledge-based work (Gillespie and Richardson, 2000, p.232), and that the dependence of knowledge workers on periods of intense face-to-face interaction ensures that telecommuting will remain a part-time practice, at least for the time being.

Through mobile telecommunications, however, travel time is no longer 'dead time' as we can now reach, and be reached by clients, colleagues, and friends while *en route* (Lyons and Urry, 2005; Sheller and Urry, 2006; Urry, 2006). Because of this effect, the perceived cost of travel is lowered and so, paradoxically, by freeing employees to work from nearly anywhere, mobile office technologies may actively encourage workers to locate further from the office than ever before (Mokhtarian, 2003; Mokhtarian et al., 2004). Since trains now permit travellers to charge laptops, send email, and place and receive calls, perhaps the greatest long-term advantage of public transit over private vehicles may well prove to be the fact that people can perform much more complex tasks without placing themselves, or others, at risk of an accident.

Organisational Proximity: Finally, Torre and Rallet (2005) add to our understanding of distance by introducing the concept of an 'organised proximity' that can be defined as: "the set of routines—explicit or implicit—which allows coordination without having to define beforehand how to do so…[these] routines incorporate organisational structure, organisational culture, performance measurement systems, language and so on" (Rallet and Torre, 1999, p.375). In a sense, this idea actually combines the 'logic of belonging' and the 'logic of similarity' that we covered in the review of social networks and types of proximity (Watts et al., 2002), but it is also obviously relevant to our understanding of the knowledge economy. This also sheds additional light on our understanding of clusters: their social dimension is what allows workers to develop the 'routines' that will allow them to collaborate when necessary, while still competing with one another intensely on a day-to-day basis.

Grabher (2001) elaborated on these ideas in an study of the Soho advertising cluster, finding that its heterarchical organisational structure nonetheless permitted identification amongst employees with both 'the Group' of multinational advertising firms (*e.g.* WPP or Ogilvy & Mather), and 'the Village' of independent contractors and studios (2001, p.353). In both cases, heterarchy promotes diversity, ensuring an ongoing adaptability to client needs (2001, p.360), while also enabling the emergence of a kind of diffuse trust built around social and working norms (*e.g.* work hard/play hard) and a latent network of personal relationships that can be activated at-need (Grabher, 2001, p.371; Grabher, 2002, p.208).

So to some extent spatial transaction costs can be managed organisationally (Torre, 2008, p.879), potentially negating the 'lock-in' effect caused by the difficulty of transferring various types of knowledge (Knoben and Oerlemans, 2008). However, even though organisational proximity is a powerful concept for explaining how a firm can successfully manage a distributed working environment, the inescapable fact remains that distance-enabling tools such as email and videoconferencing still work 'better' with people that you know, and that new relationships still seem to require, or are at least significantly improved by, face-to-face initiation (cf. Cook et al., 2004, p.19; Torre, 2008, p.877).

Technology

An early sales pitch for Hewlett Packard's videoconferencing system was quite explicit about the limitations of voice-only calling: "You've just finished making your pitch to the board and there is complete silence on the end of the line…are they nodding their heads in agreement?" (Economist, 2007a) However, the historically poor quality and accessibility of video conferencing services meant that they played only a small role in the communications activity of even such wealthy and enthusiastic adopters of new technology as the financial services sector (Faulconbridge, 2007, p.1647). In addition to the growth of Skype (see page 170), there is new evidence of the growing popularity of video calling: Economist (2009b) notes that live video traffic on the Internet is growing at a rate nearly double that of other forms of electronic interaction, and Matson and Prusak indicate firms can use 'videoconferencing and occasional in-person meetings' to "bridge physical distances and build relationships" (2010, p.2).

Hi-tech firms often make for particularly interesting case studies into the effect of technology on remote interaction since they tend to have global production chains and employees who are particularly receptive to collaboration via telecommunications. Cisco is no exception, and as a matter of corporate policy it, in the inimitable language of business, 'eats its own dog food': in 2009 the firm averaged 5,500 internal telepresence meetings a week and the company reports that it has cut its travel budget by nearly 50%, saving $290 million (Economist, 2009b). However, whatever the success of High Definition (HD) video conferencing, one of the clear ironies of this shift away from long-distance business travel is that senior management find themselves called into the office at all hours of the day and night in order to 'meet' with vendors and clients because the bandwidth and hardware required are not (yet) available at home.

Spatial Implications

Torre (2008) treats organisational and geographical proximity as orthogonal (see Table 5.3): geographic proximity can exist without organised proximity, and vice versa. In the former case, there is no foundation upon which to build a platform for exchanging knowledge and so you have 'spatial concentration without spillovers'. In the latter case, the existence of an epistemic community means that there is less need of physical proximity for knowledge transmission. Where both types of proximity coexist then Torre sees this as a classic localised cluster, and this distinction brings additional conceptual clarity to our consideration of clusters in Chapter 4.

	Geographical Proximity	Organised Proximity
Geographical Proximity	Spatial concentration of activities (without knowledge spillovers)	Cluster with local knowledge transfer
Organised Proximity	Cluster with local knowledge transfer	Footloose epistemic community

Table 5.3: Role Played by both Types of Proximity in Knowledge Transmission (after Torre, 2008, p.879)

The epistemic community also gives us a useful tool with which to understand how the combination of temporary and virtual proximity can act as a functional—even if not necessarily ideal—substitute for the sort of dense physical clustering that is thought to be so essential to creative fields. Indeed, the ability of technology to support more extended epistemic communities may well be driving the continued growth in long-distance business travel (Asheim et al., 2007, p.666) because it enables the community to survive long periods without close contact. However, to truly thrive the community still seems to require F2F interaction, and although I've tended to frame this all in terms of meetings, it should be clear from the discussion of strong and weak ties in Chapter 4 that the reinforcement of norms and the development of new contacts also occurs in informal contexts; as one European animator puts it "the most effective part of the Cartoon Forum [trade fair] is probably the bar" (Cole, 2008, p.898).

Finally, Torre (2008, pp.882–883) also suggests that the need for F2F varies with the phase of the production process—that the requirement for geographical proximity diminishes with time and can be largely replaced by organised proximity when processes are codified. Certainly, the evidence we have seen so far indicates that this *is* a factor; however, the discussion of knowledge bases and of the relative merits of F2F highlights the fact that when complex issues are involved then there is still no substitute for F2F interaction. So although a location outside of London might be entirely feasible for non-client facing staff, even here we find that there are distance constraints if the back office activity depends upon intimate—which is to say tacit—knowledge of, say, City practices and clients (Cook et al., 2004, p.34).

Summary

We can now pull together the many threads of an argument around the continued importance of F2F contact in an era of advanced ICT. As we saw in the section on buzz (see page 154), meeting in person is a particularly costly way to do business; however, the many levels on which copresence works in practice makes it a very efficient way to communicate a great deal of complex, uncertain information while minimising the risk of misunderstandings (Cook et al., 2004, pp.18–19). At a time when the acquisition and exchange of knowledge acts is the cornerstone of a firm's response to uncertainty (Faulconbridge et al., 2007b, p.12), colocation "creates favourable pre-conditions for F2F and, consequently, accelerated localized learning" (Grabher, 2002, p.209; Buck et al., 2002, p.112).

Foreign Exchange (FX) is a particularly good example of the challenges facing modern firms that depend on the successful exchange of complex, dispersed knowledge (Clark and Thrift, 2003). Since trading takes places around the clock, positions need to be handed off from one office to the next in an orderly way (2003, p.15). In the case of the FX sector, this can done through a combination of geographic proximity within each market—the traders are usually physically close to one another as a way of improving communication and awareness, even if the trading floor is no longer as noisy as it once was (2003, p.20)—and organisational proximity between markets—traders coordinate around sets of practices and norms that enable them to communicate effectively with workers in another office and culture. Supplementing this are events that 'engineer' sociality: staff from around the world meet up regularly to celebrate success and talk shop (2003, p.21).

Of course, firms can also (re)configure themselves so as to decrease relational distances: the 'culture' within a software firm (*i. e.* synthetic) tends to be shaped by the culture of its client industries, while the cultures of advertising (*i. e.* symbolic) powerhouses such as Ogilvy & Mather ('emotional') J. Walter Thompson ('scientific') reflect an agency ethos of how to do projects (Grabher, 2004, p.110). Cook et al. (2004, p.27) claim that, as financial products become easier to copy, firms increasingly compete on their service levels and bespoke solutions: they now invite prospects to their offices in order to show off the 'firm culture'. In other words, MNEs have actually begun to use the social characteristics of their office as a defensible competitive advantage.

So the concept of 'relational proximity' offers us a more generic way to think about how firms might navigate between the various options presented by permanent, temporary, electronic, and organisational proximity. In effect, relational proximity is what helps to bridge the gaps within an office and between the dispersed offices of an MNE—Asheim et al. (2007, p.659) associate it with the effective transfer of tacit knowledge and root it in "shared values, shared visions, [and] shared vocabulary…" It is these features that allow Cole (2008, p.892) to conclude that while colocation may represent a 'best practice', it is no longer the *only* one.

5.4 Knowledge Work

Key Sectors

We have now explored the ways in which knowledge is created and transmitted, but to be able to analyse telecommunications flows in Chapter 7 we first need to define knowledge work in a way that connects this evolving understanding to the existing industrial classifications. This will require a more directly sectoral approach and while some, such as the one set out in Table 5.4, draw on the OECD definition—which includes high- and medium-tech manufacturing, and value-added 'knowledge intensive' market services such as finance, insurance, telecommunications, business services, education, and health (Brinkley, 2006, p.14)—others focus on 'professionals' such as solicitors, accountants, management consultants, financiers, researchers, engineers, architects, and software developers (cf. Goddard, 1975; Keeble and Nachum, 2002). So although Brinkley (2006, p.14) improves on the OECD definition by including employment in cultural industries as well[2], it is nonetheless clear that "no single definition will capture all aspects of the knowledge economy" (2006, p.29).

[2] In the following review of the 'key sectors' in the knowledge economy I will not deal directly with financial services since we have explored this field extensively in the preceding chapters.

Table 5.4: Value of Knowledge Work (Brinkley, 2006, p.11)

Exports (£ billions)	1995	2005
Business services	10.9	30.7
Financial services	8.6	24.8
Computer services	0.8	5.8
Communications	1.0	3.0
Cultural/media	0.7	2.0
Government	1.4	2.0
Royalties/licenses	3.9	7.3
Knowledge services	**27.3**	**75.6**
Non-knowledge services	23.3	35.5
Total services†	**50.6**	**111.1**

†All figures current prices, balance of payments basis. Totals may not sum due to rounding.

Moreover, just as working in an office does not guarantee an information- or knowledge-rich environment, *not* working in an office should not be taken to demonstrate an absence of knowledge-work. But if knowledge workers can be found outside of the more obvious spaces of information work, then the coarse traditional classifications may be unreliable (Goddard, 1975, p.3). In turn, this implies that we should consider the role of the division or office within the firm as well; but this is an altogether more difficult proposition analytically since, to date, that level of detail has only been available through expensive qualitative investigation. In

Chapter 6, I intend to show the ways in which new, computationally-enabled methodological approaches are beginning to overcome this historic limitation.

Gillespie and Green (1987, p.400) define business services as an "externalised extension of the division of labour in management", and indicate that these services are diverse both in terms of what they offer to businesses and in terms of their spatial strategies. The value of outsourcing management and administration tasks stems from rising levels of competition and rising rates of technological change, both of which mean that firms face significant risks if they make substantial investments in non-core functions (Wood, 2006, p.349). This is especially true where there are significant costs and little opportunity to reap economies of scale in return.

Business Services: Within the general category of business services, those that are intensively involved in knowledge generation and application—termed Knowledge Intensive Business Services (kibs)—fall into two groups: the lower-order routine functions associated with the 'back office' and the higher-order ones associated with business and product development. A good deal of kibs growth in the U.K. has been of the more routine functions, and Wood (2006, p.340) argues that such firms are usually attracted to 'property-led office developments with an accessible workforce and good communications'. In contrast, the higher-order services will generally involve more complex exchanges and decision-making, and so a good deal more f2f interaction is expected (Coffey and Shearmur, 2002, p.376).

The nature of kibs work means that demand for their services is often funnelled through a head office (Gillespie and Green, 1987, p.400), and so many business services are fairly tightly clustered in the largest cities (Bennett et al., 1999). As a result, it is hardly surprising that Central London possesses almost three times the average kibs employment share of the other core U.K. cities, and over 50% more jobs than all the other cities combined (Wood, 2006, p.341). However, most kibs are small to medium-sized businesses and may depend on just a few major clients even though they may operate in a global market (2006, p.347)[3]. Some 'higher-order' kibs firms in the capital may be so specialised that they actually find it advantageous to outsource some of *their own* routine functions to lower-order firms in cheaper locations: according to Wood (2006, p.346), two-thirds of kibs purchases in 2003 were actually from other kibs.

[3] This, of course, links us back to the earlier discussion of scale and transportation in Chapter 4.

Cultural Industries: Recent work by Florida (2002a,b) and Currid (2007) has shifted attention to the importance of cultural industries. This reflects a welcome rebalancing of an analysis that has all-too-often favoured the measurability of 'high-tech' firms through patenting activity at the expense of equally important, but harder to measure, symbolic output. However, some of the subsequent work in this field has, at times, bordered on being an advocacy campaign for nightclubs and restaurants instead of a considered explanation of how and when cultural industries form sustainable knowledge-production complexes, especially outside the major centres such as London, New York, Paris, and Tokyo (MacGillis, 2010; Little, 2010).

In spite of this limitation, it is helpful to recognise that cultural production *is* an important aspect of knowledge work because of the convergence between cultural and economic development (Scott, 1997, p.323). In effect, the 'use value' and 'sign value' of goods is increasingly indistinguishable, and there is growing demand "for goods and services that serve as instruments of entertainment, communication, self-cultivation, ornamentation, social positionality…[that] exist in both 'pure' form (film, music) or in combination with utilitarian functions (furniture, clothing)" (2001, p.12). And perhaps more than in most other sectors, in cultural industries the supply of, and demand for, products is characterised by feedback effects that reinforce one another (*ibid.*).

Cultural industries are generally thought to include: media such as film, music, and publishing; various types of fashion such as clothing, furniture, and jewellery; services such as advertising and entertainment; and the 'commercial art' professions such as architecture, and graphic and web design (Scott, 2001, p.16). Many researchers also count the 'fora' of museums, art galleries, restaurants, bars, opera houses, and libraries as part of the cultural infrastructure. Certainly, these venues constitute a shared resource that no one industry on its own could sustain, and the concentration of institutions in large American cities helps to explain why more than 50% of the three million culture workers that Scott (2001, p.16) identified in his research could be found in metro regions containing more than one million people. Meanwhile, metropolitan London accounts for 26.9% of cultural employment in Britain (*ibid.*), but only 12% of its population.

Currid (2007, p.7) makes a strong case for the cultural economy being much more fluid than usually imagined by people "who see art, music, film as separate endeavours." Cultural output often combines many different strands of work—there is research, production, and marketing, for instance—and relies on a 'motley crew' of collaborators in a sector where 'nobody knows' which products will succeed (2007, p.77). These combined pressures mean (as we have already seen at several points) that there is a reliance on many small contracts and on the reputation of collaborators to reduce risk.

The other differentiating dimension of cultural products is that they are consumed *socially*—it is, again, the importance of what designers hear and singers wear—and that many people are simultaneously producers and consumers (Currid, 2007, p.7). So while buzz matters to many industries, it is considered vital to the functioning of the cultural market where goods are of an inherently 'uncertain and taste-driven nature' and their value is often ambiguous or has applications beyond their inherent 'use value' to the purchaser (Currid and Williams, 2010, p.4). Cultural products send socially-coded signals, but the place-specific characteristics of culture also create effective, defensible ways for firms to differentiate products in a competitive environment (Scott, 1997, pp.324–326). A few places acquire such durable reputations for distinctiveness and quality (*e.g.* Champagne), that copies from another location are still considered to be imperfect substitutes (2001, p.14).

The binding of culture and place is why we speak of West End theatre, Broadway shows, and Parisian dining, but foremost amongst these locations is undoubtedly Hollywood, where the feedback loop between Hollywood the place and Hollywood the creative production complex reinforces the desirability of both. This relationship explains why Scott (1997, p.325) argues that cultural industries "tend to be rooted in dense recursive relations between place and logic of local production system"; moreover, the link between place and product serves to 'authenticate' the output for consumers and yields a kind of monopoly rent that explains why cultural producers are willing to pay the high costs of living and working in global 'signifying locations' (*ibid.*).

Of course, over time these effects may weaken as new artistic and cultural trends emerge, but the most competitive sites also build up social and physical assets—what Currid and Williams term 'magnets' of interaction (see Figure 5.2)—that are very difficult to copy from scratch: "London's universities and fashion institutes are where future designers first form networks that endure through most of their careers. Fashion designers continually used their former educational institutions as an innovation community and networking hub" (Athey et al., 2007, p.31). Cosmopolitan cities also offer an abundant supply of desirable 'quality of life' features (bars, cafés, clubs, etc.) that are crucial in attracting and retaining creative workers and in stimulating cultural output. This concentration can, in turn, attract other people and industries in a virtuous spiral of economic growth (Asheim et al., 2007, p.666; Currid, 2007, p.46).

Hybrid Firms: Although Currid's emphasis on the creative sector as a source of growth and competitiveness in New York City's economy is a welcome counterbalance to an historical focus on finance, she appears to largely exclude creative activity in historically 'technical' roles such as those found in fields like architecture and programming. However, it is quite clear that with the blending of high-technology and high-design we seem to be entering the era of what might be termed the 'hybrid' firm (Hutton, 2004, p.91). For instance, within the British economy, software design, computer gaming and electronic publishing—all hybrid endeavours by this definition—have nearly doubled their shared of Gross Value Added from 1.8% in 1997 to 2.8% in 2003, for an annual growth rate of 11% (Brinkley, 2006, p.15). In fact, with employment also growing at about 8% per annum, these three sectors account for much of the expansion in the 'creative industries' that was shown in Table 5.4.

As evidence for the existence of these firms, Hutton (2004, p.91) points to the mix of "pre-Fordist (artisanal) and post-Fordist industrial production regimes" in the inner city and to his typology of 'signifying New Economy precincts' (2004, p.93) such as SoMa in San Francisco and Hoxton in London. So, much like more purely cultural producers,

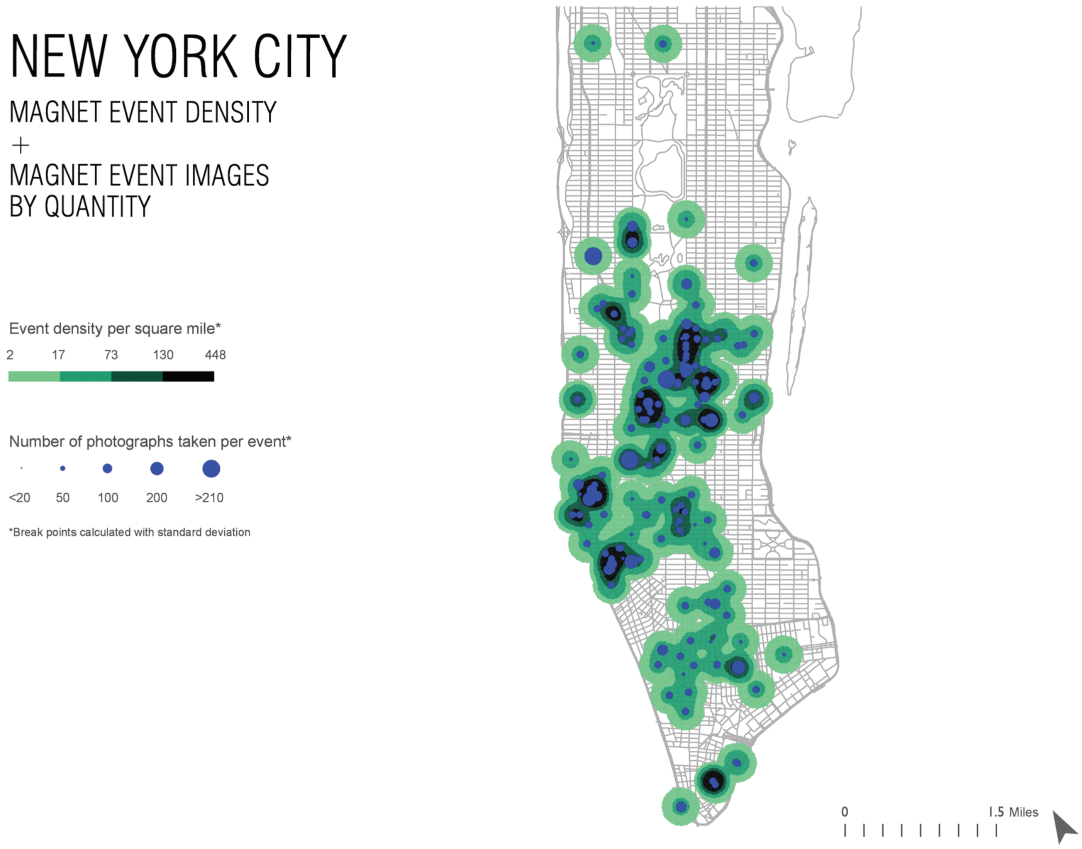


Figure 5.2: Density of 'Magnet' Events Derived from Photo Data (Currid and Williams, 2010, p.16; reproduced with permission of the authors)

hybrid firms prefer environments that support interaction, and within which the mingling of work and life enriches the local "information surface" (*ibid.*). While Hutton seems to expect that most hybrid producers will be comparatively small, it seems to me that in some cases the firms may be much, much larger: companies such as Apple and Nike are hybrid firms in that they blend cultural inputs with ICT to generate high-value products, yet they are vastly larger than the type of hybrid firm studied by Hutton. In fact, even firms that appear on the surface to be relatively traditional in terms of their output may actually operate in an increasingly hybridised manner: one designer furniture firm studied by (Morrison, 2008, p.827) employed a complex technical system to track the performance of furniture components through the entire production process.

Research & Development: The last category of interest to us in this review is traditionally known as Research & Development, although this is clearly a pretty broad category and could encompass both social sciences and natural sciences research. Although some sectors such as biotechnology and pharmaceuticals outsource a great deal of research activity, Gillespie and Green (1987, p.402) suggest that thinking of R&D as a 'service' can be misleading and that it should be considered part of the production process. Outsourced or not, the connection to analytical knowledge generation makes it clear that the locational preferences of R&D groups may well differ from those of other knowledge-based services.

More than any other knowledge-intensive sector, it is R&D that points to the dangers of sampling just one or two industries and assuming that the conclusions are universally applicable (Gillespie and Green, 1987, p.408). In 1970, the South East of England *outside* of London contained 49% of R&D units (Goddard, 1975, p.7); and Gillespie and Green (1987, p.408) found that, nearly twenty years later, although more R&D activity had decamped from London it was still very much a feature of the Greater South East of England (GSE). Today, this pattern seems firmly embedded: the majority of Britain's innovative R&D activity—as measured by patents—falls roughly within Hall's 'Western Crescent' (see Table 5.5). From a planning standpoint, many of these firms operate from corporate 'campuses' which provide a panoply of services for workers—including banking, retailing and leisure facilities—so that staff rarely need to leave during work hours and there is comparatively little of the kind of face-to-face social interaction that characterises, say, finance or fashion in London.

Top five performers		Bottom five performers	
Cambridge	80.8	Doncaster	3.1
Oxford	50.1	Luton	2.9
Birkenhead†	35.0	Sunderland	2.3
Swindon	34.4	Blackpool	1.6
Reading	30.7	Grimsby	1.6

† My own limited research suggests that the presence of Birkenhead in this list may be due to the activities of one or more legal firms specialising in Intellectual Property law, and not to 'innovative activity' *per se*.

Table 5.5: Patents per 10,000 people in England's largest 56 urban areas (Athey et al., 2007, p.15)

Particularly in the case of R&D activity, it is internal knowledge flows that seem to predominate, and there may little in the way of a wider local community (Athey et al., 2007, p.30). In the case of MNEs, this approach may explain why domestic collaborations make up a declining share of partnerships, and why international inward investment to the U.S. increased from $1.5bn in 1980 to $22bn in 1998 (Echeverri-Carroll et al., 2007, p.714). The international commissioning of R&D means that national measures of research output may be misleading as a guide to overall activity (Brinkley, 2006, p.10).

That said, as we saw in the section on the analytical knowledge base (see page 166), innovative firms—and especially the smaller firms and entrepreneurs who seem to 'rely more on local sources of innovation and inspiration' (Sonn and Storper, 2007, p.1033)—may well still see some advantage to local collaborations with universities as both a source of innovation (Athey et al., 2007, p.32) and a source of skilled labour (Vorley and Smith, 2007, p.177). There is also evidence to support the idea that academic institutions can play a vital role as a trustworthy partners for, or brokers between, between firms concerned about the leakage of intellectual property to competitors (Athey et al., 2007, p.31), but it is significant that these relationships are often formalised quickly (Moodysson et al., 2008, p.1043).

R&D is probably the most well-researched of the four categories of knowledge work that we have considered here—and several creative methodologies, such as those developed by Jaffe et al. (1993), Henderson et al. (1998), or Sonn and Storper (2007), have focussed on patenting activity, especially in the high-technology sector, as a proxy for R&D activity in general. From a research standpoint, patents have several advantages: in many countries, applications are searchable electronically and allow researchers to zero in not only on a generally-accepted marker of innovation, but also to mine the relationships embodied in the patent's citations and in the social network characteristics of who works together on which patents (cf. Das and Finne, 2008; Torre, 2008; Gallié, 2009). In short, patents are what tends to be measured because patents are what are measurable[4]; however, it is also clearly just one indicator and the importance of non-patentable innovation should not be overlooked (Athey et al., 2007, p.20).

[4] There are, however, significant shortcomings with this approach when it used for local and regional analysis outside of America and Germany because of issues with the data; this has become even more problematic with the increasing relevance of the European Patent Cooperation Treaty (Van Dulken, 2010).

SUMMARY: A recent study of the Phoenix, Arizona metro area supports this general model: ÓhUallacháin and Leslie (2007, pp.1598–1599) found that, overall, R&D had the lowest level concentration, while legal services, accounting, business support had the highest. And, as might be expected, architecture and engineering were clustered, but were not found in the CBD (2007, p.1598), which only reinforces the earlier findings from Montréal, Canada (Coffey and Shearmur, 2002). Overall then we have general support for the idea that knowledge 'spillovers' are spatially constrained, and the extent of the constraint is connected to the complexity of the product or service (ÓhUallacháin and Leslie, 2007; Gallié, 2009). We can also think of this dynamic as 'spatial economies of synergy' meaning that there is a value—innovation—attached to being located in a place where there is a potential for interaction with others (Castells, 2009, p.9).

Knowledge Workers

One of the most striking features of the knowledge economy is that, even as increasingly sophisticated technology is displacing routine activity, it is increasing the demand for skilled, creative staff. This has always been true for cultural goods and services since they are dependent upon "large inputs of human intellectual and manual labour, even where ICT plays a major role" (Scott, 2001, p.16). But the complex workflows embodied in many outputs will increasingly require employees to act in a flexible fashion, and so we may expect a flattening of the corporate hierarchy in the coming decade (Economist Intelligence Unit, 2006, p.7). Drucker (1999, p.142) has argued that, more than other classes of worker, knowledge workers will need to be able to manage themselves, and two-thirds of executives interviewed by the Economist Intelligence Unit intend to give their employees greater autonomy (2006, p.81).

However, reflecting the complexity of the knowledge economy, there is some confusion as to just how many people are engaged in this type of decision-making work in Britain. Part of the confusion stems from the overlap between knowledge work and services in general: depending on where we draw the line between basic services, information work, and knowledge work we will get very different levels of engagement. Using the 1981 census, Goddard and Gillespie (1986, p.385) reported that 45% of British workers could be classified as 'information workers', but fully ten years later Castells (1996 [2000], pp.323) was indicating this number was only slightly higher at 46%. And more than ten years later again, Shaw and Jefferies (2005, p.38) claimed only that 50% of British employment was in the more broadly defined service sector, although the size of of the 'Other Industries' section (typically 30% per region) suggests that we're facing a definitional issue.

Regardless of the exact number, the core driver of this sustained increase in *all* services (see Table 5.6) seems to be the fact that "…firms in all sectors of the economy—from mining and manufacturing to finance and consumer services—buy more intermediate service inputs…" (Sassen, 2002, p.16). Overall, services employment growth seems to have been split between skilled sectors requiring high levels of educational attainment, such as many of the 20% of employees in the banking and finance categories, and lower-skill sectors such as the travel and hospitality industry (Green and Owen, 2006, p.25). However, the rates for these two types of services have been very different: between 1995 and 2005 the export of specialised services grew by more than 100% compared to 'just' 50% for more traditional service exports such as transport and travel (Brinkley, 2006, p.11).

Occupations	1984	1994	2004	2014 (Projected)
Knowledge Workers†	31%	36%	41%	45%
Personal services‡	25%	28%	28%	28%
Skilled/semi-skilled; manual	28%	23%	19%	18%
Unskilled	16%	14%	11%	9%

† Knowledge economy jobs are managerial, professional, associate professional standard occupational classifications.

‡Personal services include care, recreational, and some hospitality jobs, sales; admin/clerical.

Table 5.6: Knowledge workers in the U.K. economy 1984–2014 (adapted from Wilson et al., 2006, p.70 by Brinkley, 2006, p.19; reproduced with permission of the authors)

Linking Table 5.6 back to our earlier discussion of tacit and codified knowledge (see page 165), Brinkley et al. estimate that these changes in employment structure are leading to the emergence of a 30–30-40 workforce in Britain where 30% of jobs involve extensive use of tacit knowledge, 30% involve some tacit knowledge content, and 40% are largely codified but not automated (2009, p.4). But we should bear in mind that knowledge workers cannot be solely described by titles or education levels. Brinkley et al. (2009, p.5) indicate that some 20% of 'high-knowledge content' workers are not graduates, and the management writer Peter Drucker has noted that a "tremendous amount of knowledge work includes *manual* operations" (1999, p.141).

Technology and Knowledge Work: Quite obviously, as more and more economic activity is connected to the 'generation, processing and exchange of information', then factors affecting these aspects of firm operation will have a greater and greater impact (Goddard and Gillespie, 1986, p.383). The focus of technology investment is therefore likely to shift from the more obvious economies of scale and automation towards making knowledge workers more productive (Economist Intelligence Unit, 2006, p.7). Drucker, notes that:

> the most important, and indeed the truly unique, contribution of management in the 20th century was the fifty-fold increase in the productivity of the MANUAL WORKER in manufacturing. The most important contribution management needs to make in the 21st century is to increase the productivity of KNOWLEDGE WORK and the KNOWLEDGE WORKER.
>
> *1999, p.135 (Capitalisation in original)*

So we may expect that the focus of investment this century will be in the processes and activities that are the most difficult to automate, and in particular in "new collaboration and communication tools; new ways to store, filter and retrieve unstructured data; and decision-support tools that expand and enhance knowledge workers' ability" (Economist Intelligence Unit, 2006, pp.78–79).

The interest in using technology to augment collaboration and communication seems particularly important since many of the areas in which the Economist Intelligence Unit's respondents see the most scope for productivity growth—such as customer support, business development, marketing and sales, and knowledge management—involve intensive working across organisational boundaries (2006, p.7). But even in less overtly outward-oriented jobs, innovation will introduce fundamental changes: for instance, in the healthcare sector we can expect to see computers performing increasingly sophisticated diagnostic and monitoring tasks, leaving the physician to focus on the complex tasks of making diagnoses, selecting treatments, and communicating with patients (2006, p.54).

Another way to get at the differential impacts of technology on workers is to turn to a task-based categorisation established by Levy and Murnane (2007) which identifies five different classes of workers: expert thinkers, complex communicators, routine cognitive workers, routine manual workers, and non-routine manual workers. For expert thinkers, computers serve to make information more accessible but cannot substitute for the judgement of the worker as there are no formal rules to guide choices. The complex communicators group is composed of workers—such as managers, teachers, and sales executives—whose primary task is communication with others.

In contrast, the routine cognitive (*e.g.* bank branch workers, claims adjusters, etc.) and routine manual workers (*e.g.* factory and farm workers) tend to perform simpler tasks whose scope can be defined by rules and sets of well-defined procedures. Critically, the improving performance and power of computers makes *both* of these latter types of tasks amenable to automation within the constraints outlined above. The final group of non-routine manual workers (*e.g.* truck-drivers and cleaning staff) perform tasks that are not considered intellectual, but which are hard to define by rules because of the environment in which they are performed.

Roles, Rules & Creatives: So we can think of knowledge-work as requiring a particular set of educational and/or aptitudinal requirements that can only be met by specific individuals and groups—neuroscientists, mathematicians, singers, artists, and so forth—whose work cannot be scripted or proscribed. At the other end of the scale is role-based work, such as data entry, that can be fulfilled, at least in theory, by any human being with some modest level of procedural training; and we are at the point where we may soon see automated systems begin to substitute for people in low-value training roles (Hall, 2002a, p.275). The point is that the individual skills and attributes of the human being in a 'role' are relatively unimportant to the firm, and their work is often designed so that the employees are functionally interchangeable. This is a 'services factory' in which firms can reap economies of scale through massive concentrations of labour in less expensive locations.

In the retail segment of financial services, the Economist Intelligence Unit (2006, p.44) anticipates that banks will move forward with the centralisation of back-office work at just a few global processing centres where they can secure further savings on transaction-related costs. Increasing sophistication in the training of, and computerised support for, employees in how to handle clients from another country means that we are likely—within the cultural and linguistic constraints set out earlier (see pages 49 and 85)—to see the role-based jobs amenable to remote interaction continue to disappear from high-cost regions. However, the impact, especially on skilled workers whose skills are no longer needed, may be severe; a former administrative assistant interviewed by the *New York Times* and now working at Wal-mart reports her frustration: "A monkey could do what I do…Actually, a monkey would get bored" (Rampell, 2010).

In the middle range are jobs that I would call rule-based: they are distinguishable from role-based employment in terms of the degree of individual agency, but they are nonetheless not creative employment in a meaningful way. I would argue that rules-based work may still involve high levels of training—the level of specialisation means that staff are no longer functionally interchangeable to the same extent—but organisational policy constrains the range of activities and of decisions quite tightly. So one example of a 'rules-oriented' worker would be the technician responsible for maintaining desktop computers or network hardware at large corporations (Economist Intelligence Unit, 2006, p.72), and another would be the drilling engineer responsible for monitoring boreholes (2006, p.80). Both of these jobs involve a great deal of knowledge acquisition and application, but technological change, through standardisation and increasing sophistication, seems likely to have structural and permanent impacts on such jobs.

So while it may be difficult to imagine automated tools fully replacing the set of skills required to diagnose a misconfigured router or an application failure, the growing power of software agents and the scope for remote manipulation or interaction means that fewer such people are required to accomplish the same work. The engineer may no longer need to travel in order to diagnose and correct issues, and may be able to perform the same work from a console anywhere in the world that sufficient telecommunications bandwidth is available. Objectively, it is probably here that new ICT-enabled tools are having the greatest impact on workers at the start of the 21st Century—productivity has been extended to such a degree that structural unemployment seems like a very real risk even though these employees are not unskilled in the traditional sense of the word.

In contrast to these two groups, for knowledge workers the ability to collaborate with others—Matson and Prusak (2010, p.1) suggest that knowledge workers spend half their time on 'interactions'—and to identify and act on novel information will often trump established rules or processes entirely (2006, p.79). However, in the same way that there are direct and indirect services, we can distinguish different 'informational orientations' amongst knowledge workers. Towards one extreme are software developers or research scientists whose inputs are primarily codified but who, unlike role workers and to a lesser extent rule workers, such workers *do* have irreplaceable skills—so firms cannot simply trade them for cheaper labour in India, though they can certainly complement them with labour from less costly locations. Towards the other extreme are knowledge workers who depend on regular, intense, and multi-lateral knowledge flows as a way of remaining abreast of market movements, cultivating awareness of participants and of their shifting allegiances, and maintaining contact networks of opportunity. For workers in the latter category, the 'outward' orientation of such work makes an extensive, localised social network of strong and weak ties absolutely vital.

Looking to the future, the Economist Intelligence Unit even goes so far as to suggest that the "employee required to build a fail-safe network could even be an obstacle [to the firm] in the future" (2006, p.72) because as the firm seeks to become more flexible, they continue to apply outdated rules. Of course, this issue is not confined to the ICT sector alone: even firms involved in such traditional industries as pulp and paper will come—thanks to their increasing use of specialised, intermediate services—to rely on knowledge workers. But as Mark Miranda, Georgia Pacific's director of marketing, observes: "Creativity is hard; it's easy to find people who can do the books" (2006, p.35). Truly gifted knowledge workers will be seen as crucial to the success of the firm: "They [the employees of hedge funds and investment banks] are pure ideas and human-capital machines…Employees are their only factor of production, and there is a direct linkage between compensation and production" (Nader Farahati, managing director for financial services of Mercer Oliver Wyman in London, reported in Economist Intelligence Unit, 2006, p.49).

Finally, Brinkley et al. (2009, pp.24–25) grouped people who worked with knowledge in some capacity into seven categories: leaders and innovators, experts and analysts, information handlers, care and welfare workers, servers and sellers, maintenance and logistics operators, and assistants and clerks. Of these, the first three groups make up the 30% of core 'tacit knowledge workers' discussed on page 189, and the highest group of all—the leaders and innovators who have "high intensity knowledge jobs [combining] high-level cognitive activity with high-level management tasks" (Brinkley et al., 2009, p.4)—account for just 11% of the overall British workforce. The nature of their work means that these workers do not face displacement by computers; instead, they will make intensive use of computers to synthesise complex, structured and unstructured information into decision-enabling knowledge (see Figure 5.3), and 'continuous learning, teaching, and innovation' will be built into their work (Drucker, 1999, p.146).

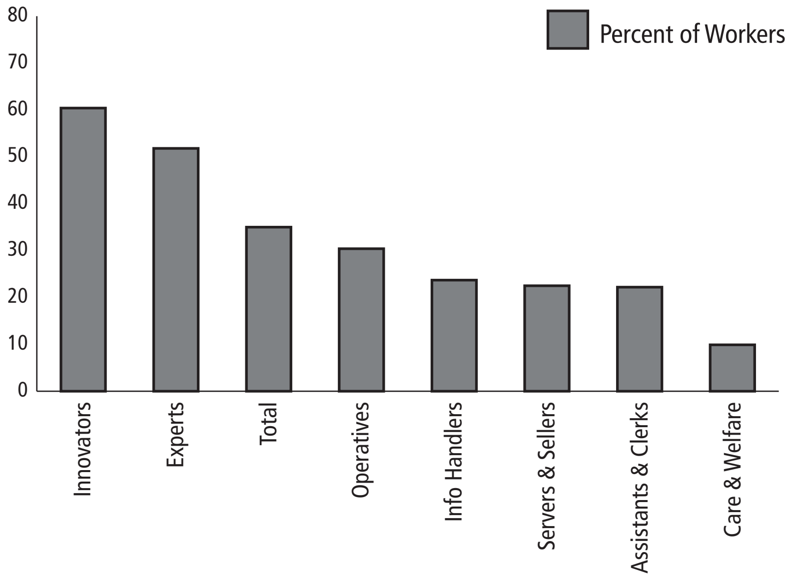


Figure 5.3: Share of workers that frequently perform at least one specialist computer task (Brinkley et al., 2009, p.29; used with permission of The Work Foundation)

The 'Missing Middle': In all of the 'hype' about the knowledge economy, it is easy to forget that 'the creatives' are likely to make up only a modest share of overall employment, and that far more people will be employed in less knowledge-intensive work. Brinkley et al. (2009, p.68) suggest that "the more excitable accounts" of the potential for knowledge work have in mind a group (their 'leaders and innovators' category) that makes up just 11% of all workers. In other words, decades of growth in various knowledge industries has still only brought us to the point where 1 in 10 workers are employed in real innovation or knowledge work with a high level of tacit knowledge and output measured in terms of patents, process innovation, and art openings. For the remaining 90% of the population, pressure to 'offshore' indirect informational services and to substitute capital for informational labour, may mean the continuing decline of mid-level 'white collar' staff (Hall, 2009, pp.810–811).

The combination of these trends means not only that the rules-based workers in the middle will be squeezed by ongoing technological change, but also suggests that many firms in the middle will be similarly squeezed between low-cost and premium-service providers (Economist Intelligence Unit, 2006, p.76). The recent popularity of netbooks alongside Apple's high-end products is a good case in point: consumers are migrating towards the ends of the spectrum where they can purchase products that are either small, cheap, and functional, or well-designed, high-performance, and luxury status-symbols (Surowiecki, 2010). And it seems that we should expect a similar dichotomy to appear in services, with a division between firms offering utilitarian, transaction-type services and those offering premium, advisory services for their 'most valuable' customers and those contemplating a high-value purchase.

The logic behind this division in industries such as financial services is straightforward: routine tasks such as payments and transfers are easily handled now through voice-activated automation, freeing more costly call-centre staff to handle complex queries (Economist Intelligence Unit, 2006, p.59). And if we compare the cost of a call centre with the still higher cost of F2F service in a branch, then it is only logical that branches will ultimately provide only those services which are neither routine, nor low-margin. A walk through a high-street bank branch of HSBC today will show a row of phones and terminals through which consumers interact with a call centre; and the aggressively expansionist Washington Mutual (WaMu) created and patented an 'Occasio' branch design that seemed to be a mix of open plan office and coffee shop (with mortgage advisers available until 10 p.m.)[5].

[5] I also recall holding a Chase account in New York in the late 1990s for which I was charged a fee whenever I spoke to a teller in a branch to complete any transaction that could also have been completed online or over the phone.

Projects, Teams & Communications: So ICT has enabled both the optimisation of supply chains and an increasingly fine-grained segmentation of knowledge work, but there is a limit to how many efficiencies can be squeezed out of such a system. As senior-vice president of Blyth Inc., a $1.6 billion designer and marketer of home products, notes: "the reduction in the number of warehouses reaches a level where it does not add much value. At some point you have to go beyond price" (Economist Intelligence Unit, 2006, p.34). Competitive advantage in a knowledge economy does not depend only on efficiency and cost—these are, or should be, a requisite for all businesses—and firms will need to cultivate their "ability to innovate, respond just-in-time, focus on quality, and establish more cooperative inter-firm and intra-firm relationships" (Garcia, 2002, p.54). This type of work has always been common in knowledge-intensive sectors where, for the most part, quality of output has been more important than quantity (Drucker, 1999, p.142), but the 'project structure' characteristic of fields such as advertising or film-making is no longer limited to what Grabher terms the "traditional 'one-off' sectors" (2002, p.206).

The spread of project-led work emphasises both internal and external communications, and "it is often better to think of it as being with a client rather than for a client" (Grabher, 2002, pp.207–208). This mode of production also requires tight integration between such historically separate functions as design, production, and marketing because changes to any of these can have repercussions up and down the supply chain. The need for firms to pursue constant innovation *while* managing complex networks of suppliers and clients implies that intra- and inter-firm communication is crucial to success (Economist Intelligence Unit, 2006, p.78). In fact, firms may well distinguish themselves on the basis of their ability to create and maintain relationships, regardless of whether this in the literal sense of a boutique consultancy's contact network (see page 145) or in the metaphorical sense of a company's brand message (*i. e.* 'Think Different'). It is, again, the culture of the firm as competitive asset that is hard for competitors to replicate (see page 181).

This dynamic suggests that the intersection between individuals and teams is of special importance—the individual maintains personal and professional relationships with suppliers and clients, while the team offers "the ability to research new market segments faster, to develop new products more effectively and to respond to customer requests with the optimal mix of skills and services" (Economist Intelligence Unit, 2006, p.48). And as Moodysson et al. (2008, p.1042) observed, the team often has the advantage of transcending spatial, divisional, and hierarchical boundaries, promoting the circulation of information and knowledge. So as long as the risk that proprietary knowledge will leak out to competitors is fairly modest, then a heterarchical approach (see page 178) that promotes intensive interaction may be useful to any firm engaged in complex work, and not just to firms in 'traditionally-disruptive' sectors such as advertising[6].

The importance of communication makes it clear that one way of thinking about jobs in the knowledge economy is the degree to which a particular position is either outward-facing (*i. e.* involves interaction with people external to the firm) or inward-facing (*i. e.* involves interaction principally with people internal to the firm). The Economist Intelligence Unit (2006) made this, together with the distinction between role- and knowledge-based tasks, a cornerstone of its *Foresight 2020* publication[7]. This approach yields five general categories: first, those who employ complex knowledge and are primarily outward facing; second, those who employ complex knowledge but are primarily inward-looking; third, the group who use 'simple knowledge' in roles that are rules-based and outward-facing; fourth, a group that is rules-based, but inward facing; and the fifth group is involved in non-knowledge, production-oriented roles. When asked to rank the value of these different classes of worker to their firm, CEOs and other decision makers made their preferences abundantly clear (see Figure 5.4).

[6] The heterarchical approach has been tried elsewhere—British Telecommunications plc. planned at one point to divide itself into smaller, competing components (Economist Intelligence Unit, 2006, p.82)—but with mixed success, possibly because most infrastructure seems to have natural economies of scale that preclude smaller organisations. Software, however, does not suffer from such limitations, and this may explain why telecoms providers are shifting their focus towards software-enabled services such as 'app stores' (Economist Intelligence Unit, 2006, p.69).

[7] In fact, I had arrived at nearly the same classification entirely independently based on my own reading and was rather dismayed to discover that the Economist Intelligence Unit had beaten me to it by about three years.

Technology

In the case of physical outputs, there is an expectation that technology will enable even very complex tangible products to become modular (*i. e.* flexible) in nature—Tata Motors envisions a car that can be assembled by dealers on-site (Economist Intelligence Unit, 2006, p.26)—so that suppliers and firms can produce parts in high volume but personalise the delivery to the end-user. In the case of intangible products the

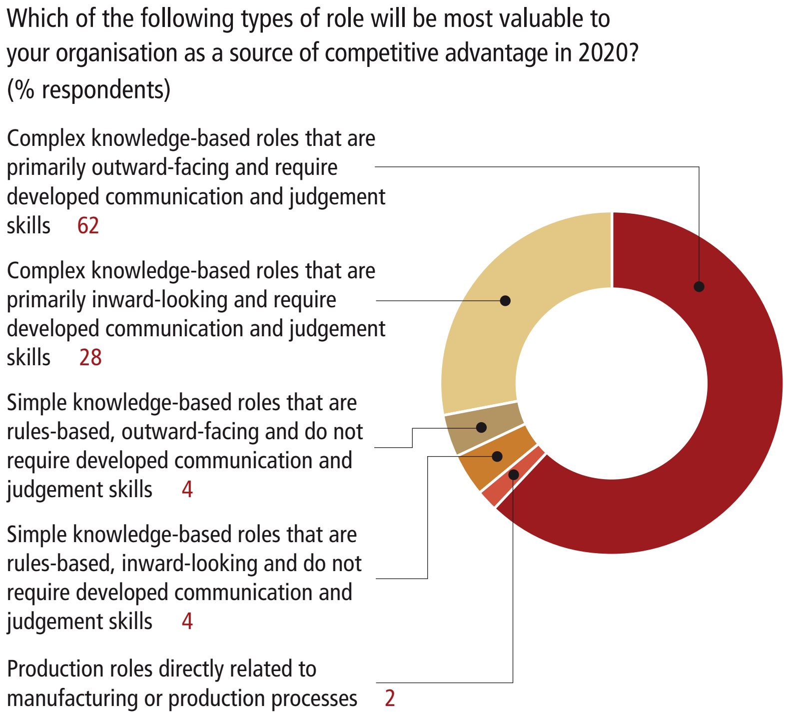


Figure 5.4: Expected Value of Different Types of Workers (Economist Intelligence Unit, 2006, p.79; reproduced with permission of The Economist)

situation is more advanced: a less obviously radical, but no less innovative at the time, example of technology-enabled customisation can be found in the way that Amazon deployed localised web sites (*i. e.* sites that use the appropriate language, domain name, and presentation format for a particular country). Even though transactions and inventory were largely managed from America, Amazon improved customer acquisition and retention by offering a customised 'local' store (Dodge, 2004, p.224).

The picture is more complex for services because ICT can operate as an augmentation of, rather than a substitution for, costly F2F interaction—this is the case of, for instance, contact management software and corporate wikis: they are an attempt to codify 'best practice' but do not fundamentally replace knowledge work and the importance of proximity (Grabher, 2004, p.109). And as we have seen, the costs of travel and of cross-sectoral collaboration constrain the spatial flexibility of workers while also requiring substantial communication and interpersonal skills. This is why it seems significant that although levels of intra-firm 'chat' in France do not vary much between urban and non-urban firms, inter-firm communications do: 24.2% of French workers in rural firms have 'given instructions to customers or suppliers', but more than 50% of employees at urban firms have done so (Charlot and Duranton, 2006, p.1374). Similarly, 7.6% of rural staff in France collaborate in teams with customers or suppliers, but 16.1% of urban core staff do so (*ibid.*).

Given these communicational and collaborative affinities, we can reasonably expect to find team- and project-based work concentrated in cities: French workers reporting involvement with innovation and design teams account for 14.4% of workers at rural firms, 23.7% of workers in suburban firms, and 34.9% of employees based in the urban core (Charlot and Duranton, 2006, p.1374). So although *all* workers interviewed in 1997 were more likely to report interacting with clients or suppliers than they were in 1987 (2006, p.1387), the trend is much more marked in cities where staff communicate with customers at nearly double the rate of their counterparts outside the CBD. These findings link together the earlier discussion on complexity thresholds for F2F interaction (see page 175) with our improved understanding of knowledge work. And we can now more fully grasp why Charlot and Duranton found not only that urban workers communicate more, but also that they also have a greater propensity to use telecommunications. Table 5.7 summarises the usage of communications technologies by urban workers in France, regardless of their skill or education level, and serves to highlight the degree of communicational complementarity.

Table 5.7: Complementarities across media for urban workers (Charlot and Duranton, 2006, p.1386)

	Telephone	Written Paper	E-mail	Personal Computer	Internet
Voice/F2F meetings	C	S	*ns*	*ns*	*ns*
Telephone		C	C	C	C
Written Paper			C	C	*ns*
E-Mail				C	C
Personal Computer					C

Notes: C denotes a positive coefficient significant at 5 per cent in the logit estimation; S denotes a negative coefficient significant at 5 per cent in the logit estimation; *ns* denotes coefficients not significant at 5 per cent.

The 'communications gradient' helps to explain an observation by Gillespie and Robins (1989, p.13) that, paradoxically, rural areas make the *least* use of distance-shrinking technologies. Another way of thinking about this issue was put forward by Meier (1962, p.139): he notes that workers in cities already border on informational overload, and so have an incentive to automate low-value message handling. In short, high-value interactions will be most effectively handled in cities, even if the outputs of the firm are of comparatively lesser value: Goddard observed that manufacturing firms had 74% of head offices and 48% of central services (*i. e.* services like those found in head offices but not actually in a head office) in the South East of England, when only 28% of 'operating units' were located there (Goddard, 1975, p.7). Goddard argued that this meant that the most important information was 'locked up' in head offices, and so 'accessibility' needed to be considered not just in terms of the physical movement of goods but also in terms of "the hidden costs of access to information". This dynamic helps to explain why staff in offices outside of London typically have fewer contacts than those of a similar grade in the capital (Goddard and Pye, 1977, p.22).

Spatial Implications

As we have noted at several points in this dissertation, there is evidence now to suggest that this absolute concentration of activity in the CBD is weakening in subtle ways: Currid, for instance, points out that there has been a steady decline in Fortune 500 firms headquartered in NYC (2007, p.55). But at the grander scale, these 'controlling' activities have tended to remain within the larger regional economy such that firms in, say, the North of England still tend to be managed from an office located in the GSE, and the demand for high-value services also originates there (cf. Goddard and Pye, 1977; Goddard and Gillespie, 1986; Gillespie and Green, 1987). This brings us full-circle to the argument that the control and coordination of peripheral operations actually increases the need for the clustering of specialised managerial functions and services at a few, critical nodes in a web of transport and communications networks (Audirac, 2002; Sassen, 2002, 2004, 2008).

That conclusion is all very well for MNEs, but what of the many small, innovative firms that provide specialist research, design, and financing services to clients of all sizes? As Hutton (2004, p. 90) pointed out: if we are in a 'new economy' then we should be able to find evidence of preferred economic spaces with "innovative industrial ensembles at regional and local levels, and fresh divisions (social, spatial, and technical) of production labour." For Hutton, these spaces were almost unquestionably to be in found in the inner city districts of older metro regions such as SoMa in San Francisco and SoHo in New York. What has helped to establish these areas as breeding grounds of new firms is that they are tightly bounded and are conducive to social interaction (Hutton, 2006, p.1822).

Echoing Jacobs (1961 [2002]), Hutton also emphasises the importance of adaptable buildings, as well as the importance of physical and psychological landmarks around which a 'signifying district' can be assembled (*ibid.*). Hutton found that the growth of the dot.com industry in Singapore's Telok Ayer neighbourhood owed a great deal to the cheap, flexible, and relatively "cosy" spaces on offer (2008, p.162), as well as to the area's proximity to the CBD (2008, p.170). In contrast, the 'manufactured' antiquity of the adjacent Far East Square seems to have proved more popular with established firms and boasts rents to match (2008, pp.165–166)[8]. Green's study of the growth of the East London fine arts 'scene' reinforces the connection between small, flexible spaces and creative working: "Furniture factories, carpentry workshops, print workshops, warehouses…[such] property tends to be well-lit and spacious, with high ceilings, and large open floor spaces…[it] is also cheap to rent or lease. Ideal, in other words, for artists' studios" (Green, 2001, p.9).

[8] Following the dot.com collapse, Hutton (2008, p.166) notes that Telok Ayer seems to have (re)adapted very quickly to cultural production, while Far East Square, despite proving popular with corporations, has lost several of its 'anchor' tenants

So for cultural and hybrid work, the inner city is conducive to new industry "because of the micro-scale ways of working, socialising, and labour market access" (Hutton, 2004, p. 92). However, the evidence produced by Asheim et al. (2007) and Moodysson et al. (2008), amongst others, suggests that this type of arrangement may be much less important for analytically- and synthetically-oriented work, though this does not mean that they cannot also benefit from local interaction effects. For instance, the popularity of 'college towns' such as Princeton and Cambridge (either one) with entrepreneurs suggests both that these are high-amenity places to work, and that they see a benefit to the opportunity to interact with researchers at the university. This may not be the kind of intense, late-night socialisation that Currid (2007) and Currid and Williams (2010) write about, but it still assigns an importance to face-to-face encounters and to these towns' proximity to major urban areas.

However, even with this added flexibility there is a certain path dependency here: in the same way that web advertisers have tended to set up shop near advertising agencies, high-tech software and hardware firms have tended to continue to locate near to the former defence sites that spawned the initial demand for their wares (Hall, 1987). Interestingly, according to Breheny (1999, p.25) video game development—which has no 'old industrial equivalent' from which it draws inspiration or income—is more closely distributed in line with total employment. But by drawing on the findings from this chapter, we can see how the difference between video games and other specialised software can also be located in part in the interaction requirements and contact patterns of the two fields: many employees at Oracle or Microsoft may be called on to travel to client sites for integration, training, or troubleshooting, but game developers are delivering a dispersed, consumer product without a specialised market or concentrated demand from which they would benefit through proximity; they are thus free to pursue more distributed, amenity-oriented locational strategies.

This combination of factors helps to explain why, even where firms *have* moved out of London, they often have not moved very far: 85% of relocations between 1964 and 1977 were within the GSE area (Goddard and Pye, 1977, p.19). Ten years later, even with the growing use of ICT to support inter-office interaction, Gillespie and Green (1987, pp.401–402) found that the relocation of back office activity still tended to peter out approximately 80 miles from the centre of London. Gillespie and Green speculated that this was the point of diminishing spatial returns where the declining cost of office space could no longer offset the rising cost of interaction, especially in terms of travel costs. So although the National Endowment for Science, Technology and the Arts (NESTA) reports that fully 90% of 'knowledge workers' were concentrated in Britain's city-regions (Athey et al., 2007, p.13), Table 5.8 (on page 200) shows just how great the concentration of this type of work in the South East really is—of the top 10 cities in the list, only two (Edinburgh and Leeds) are more than two hours from Central London by train. Over time, these effects have been compounded such that London and the South East have far outpaced the other English regions in terms of overall rates of growth (see Figure 5.5).

Rank	City	Number Employed	% of Employees
1	Cambridge	31,000	35.2
2	Oxford	35,500	33.0
3	Edinburgh	90,100	29.6
4	Milton Keynes	40,000	28.0
5	Reading	63,500	27.7
6	London	1,250,000	26.5
7	Leeds	105,600	25.3
8	Bristol	91,100	24.7
9	Norwich	30,800	23.4
10	Brighton	31,900	23.2
⋮	⋮		⋮
54	Huddersfield	16,100	10.7
55	Barnsley	7,100	10.2
56	Birkenhead	12,600	9.9
57	Blackpool	13,300	9.9
58	Hastings	2,800	9.7
59	Doncaster	11,100	9.6
60	Rochdale	7,000	9.5
61	Wigan	9,000	9.1
62	Mansfield	7,700	9.0
63	Burnley	5,500	8.7
	Great Britain	4,560,700	17.1
	England	4,060,100	17.5

Table 5.8: Knowledge-Intensive Cities (Centre for Cities, 2010, p.20)

Summary

In this section we have moved from the theory of knowledge and of knowledge transmission to the practice of knowledge work itself. We began with a review of the key sectors involved in the knowledge economy and explored the ways in which each industry embodies a distinct set of socio-spatial interactions: three of the four core sectors—business services, cultural, and hybrid firms—seem to be particularly reliant upon cities as sites for knowledge generation through access to collaborators and clients in other sectors and exposure to novel information. However, the fourth category—R&D—no longer seems to be as reliant upon urban locations, and so an important point in this chapter has been the idea that that some types of knowledge are becoming amenable to more dispersed forms of generation and exchange.

So while cities are humanity's largest artefacts, they seem to play their most important role in the knowledge economy at the micro-scale where their diversity appears to encourage, or at least to enable, innovation in the synthetic and symbolic arenas (see Figure 5.2 on page 186, for instance). The symbolic knowledge base in particular benefits from the deliberate "destabilisation of prevailing norms and practices…" (Scott, 2001, p.13), and cities stimulate this instability by bringing into contact knowledge workers from across a broad range of sectors. In

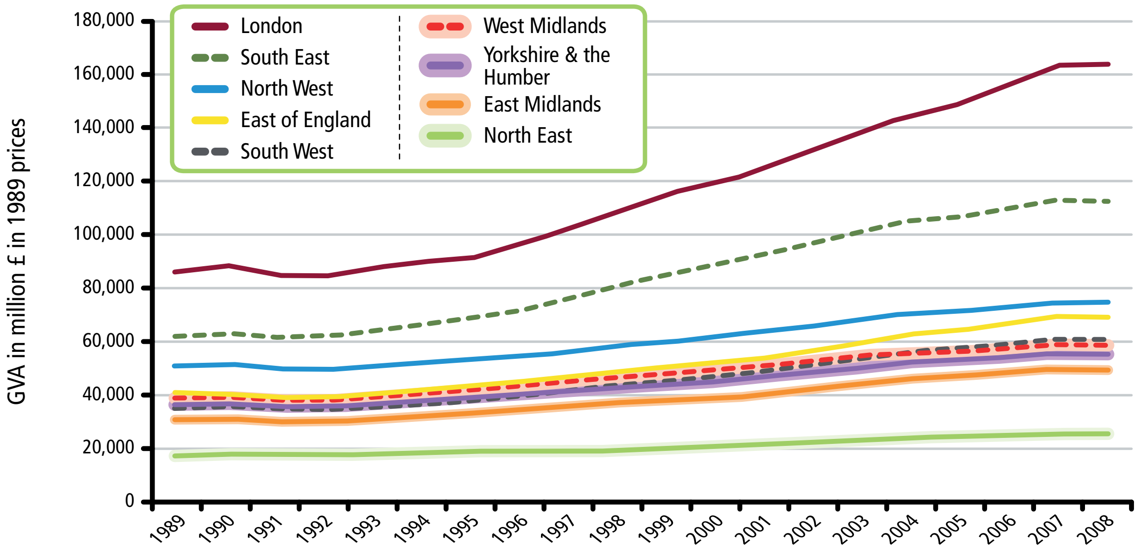


Figure 5.5: Regional Growth Rates (Centre for Cities, 2010, p.18; reproduced with permission of The Centre for Cities)

effect, as Torre (2008), Goddard (1975), and Hauser et al. (2007) have all noted, occupational structure and the relationships between actors within that structure binds together the economic and social components of regional development, and the knowledge economy makes both sides integral to innovation.

Consequently, I have also tried to connect the micro-structures of how knowledge work is done to the macro-structures of the knowledge economy itself. Thinking on infrastructure and technology has tended to focus on the value of the network (see 'Metcalf's Law' page 59), but what this section has sought to emphasise is that for most firms it is what *cannot* be put on the network that is most vital to their business. So where technology has enabled role-based work to be largely disconnected from geographical location, and it is in the process of radically altering the relationship between place and rules-based employment, its impact on creative jobs remains more modest: an augmentation, but not yet a wholesale transformation.

So in spite of the impact of technology and increasing mobility on our ability to coordinate and interact with one another, there remain four reasons why geography matters (Sonn and Storper, 2007, pp.1022–1023): first, and returning to the recurring importance of *relative* differences between inputs and outputs, the ease with which codified knowledge can be shared actually increases importance of tacit knowledge; second, the increasing use of out-sourcing and of specialised services may encourage firms to collocate for the purpose of improving coordination and collaboration; third, constant innovation makes it difficult to formalise interactions (see Theory of Spatial Transaction Patterns on page 104); and, fourth and finally, changes to the labour market in terms of contracting and churn may well require more extensive and flexible contact networks (see Labour Economies on page 127).

5.5 *Conclusions: Telecommunications & Knowledge Flows*

In this final theoretical chapter we have covered a great deal of ground, but the growing number of references to material from previous chapters points to the fact that we are beginning to draw together the many threads developed in the course of this review. We have defined knowledge in contradistinction to 'mere' data and information and, in turn, have defined innovation as the production of new knowledge—be it a new material, a brand message, an algorithm, or a financial derivative. As such, knowledge requires the the exercise of discernment or judgement, and does not result from the application of rules or procedures in a largely automated fashion. This is the case even where, as often occurs in software, new knowledge also comes from the recombination or rearrangement of existing knowledge (cf. Grabher, 2004).

Clearly, technological change has had an enormous impact on knowledge: not only has it enabled codified knowledge to be disseminated across much larger distances at much higher speeds, but it has also enabled firms to rearrange the boundary with tacit knowledge in ways that suit their activities. Wikis and blogs enable the codification of formerly-tacit knowledge, while HD video conferencing enables even some of our semi-conscious social signals to be propagated over long distances. However, where the characteristics or requirements of tacit knowledge remain beyond the reach of technology then it remains largely bound up in F2F interaction, which is where our social sensitivity to one another enables the 'parallel processing' of information in creative, intuitive, and adaptive modes of collaboration.

The knowledge bases approach enables us to further develop our understanding of when and how innovation might entail, or even require, F2F interaction. The evidence provided by Asheim et al. (2007) and Moodysson et al. (2008) suggests that analytical knowledge is less sensitive to proximity and can be transmitted in codified form (*e.g.* in journals or formulae, as software or algorithms). In contrast, synthetic knowledge tends to be more closely confined to small groups and client/vendor relationships with less formalisation, and a greater reliance on long-term interaction. Finally, with symbolic knowledge we return to the importance of many-to-many social interactions—especially in industries, such as the arts and advertising, which are characterised by constant disruption and where 'shaking things up' is desirable. Of course, no industry is purely of one type of knowledge base or another: the 'creatives' at an ad agency want to push boundaries, but their account managers want to maintain a stable client relationship and maximise agency profits. So the prevalence of each base may also vary from division to division within the firm, as well as over the life-cycle of the product, firm, or sector (Moodysson et al., 2008, p.1043). This places the dynamics of the firm (see Chapter 3) and of aggregation and clusters (see Chapter 4) squarely at the heart of the knowledge economy.

This review of the knowledge bases approach also allows us to update Scott's analysis (1983a; 1983b; 1984; 1986) of how different transaction-cost structures support different modes of production and innovation.

In some areas, such as where there are major risks connected with innovative failure, then small, tightly-focussed firms are more likely to be the drivers of innovation (examples of this approach might range from biotechnology to fashion), but codification will enable scale effects to yield competitive benefits to large firms (examples of this approach might include pharmaceuticals, and hardware or software services). This way of thinking about innovation helps to explain why Athey et al. found that "both large 'anchor firms' and SMEs are potentially important innovators": each plays different, but complementary, roles in urban innovation systems (2007, p.26).

We then turned to the characteristics of knowledge exchange and saw that, although better communication technologies enable social networks to be maintained at a larger scale both extensively (in terms of number) and intensively (in terms of frequency), in the bigger picture this has not changed the value of copresence. At the heart of my analysis of knowledge is the finding that the importance of physical proximity in innovation processes is unlikely to diminish in the immediate future. But by thinking further about F2F, we found that it plays a particularly important role in contexts that are high-risk and high-reward. Financial and cultural services are both sectors where these conditions hold; however, in less interaction-heavy sectors temporary, virtual, and organisational proximity offer alternative means of delivering many of the advantages of permanent proximity without incurring its costs. The concept of relational proximity helps us to bring all of these concepts together, and it also links the knowledge economy back to our review of the role of 'weak ties' as a source of novel information, and to the 'routines of behaviour' that are "effectively untraded forms of interdependency between economic agents [that] collectively constitute the relational assets of the regional economy" (Scott and Storper, 2003, p.586).

The commoditisation of culture has made cultural industries a particularly vibrant part of the knowledge economy, and we saw how cultural outputs, in combination with the social features of clusters, can establish very strong, place-specific 'brands'—spatial monopolies, if you will—that create a feedback effect between place and product. And we also considered the way in which cultural and technical inputs are merging in hybrid production. If we define hybrid firms more broadly, then the potential for strong agglomerative tendencies becomes very clear: advertising, for instance, is both a cultural endeavour and an advanced business service (Hall, 2003, p.143).

Finally, we considered the way that competitive advantage will increasingly depend not on routine, easy-to-automate processes but on unpredictable, hard-to-automate knowledge workers (Economist Intelligence Unit, 2006, p.7). Ultimately, we divided much of contemporary work into three broad, sector-spanning categories: roles, rules, and creatives. Role workers are employed in jobs that are increasingly circumscribed by automated systems. There is, however, still a difference between direct and indirect services, and it is indirect services—where information is, effectively, a ubiquity—that are most liable to be relocated. For rule workers the picture is slightly different, since technology here acts to augment the productivity of the rule worker but cannot (yet) replace him or her entirely. I have argued in this chapter that rule workers will be most directly impacted by the growing power of computers in the 21st century: their productivity will be extended to such a degree that structural unemployment amongst the less able (or amongst the less 'desirable', such as the elderly) becomes a real risk. On a more optimistic note, however, an ageing population may also make for new opportunities in fields where pervasive networking and cheap technology are enabling new methods of remote interaction and support.

Wherever personal interaction is an important source of information or knowledge, then jobs will be caught up in human geographies of time and place (Goddard and Pye, 1977, p.300). The importance of the strong/weak ties argument (see pages 145 and 146) as it pertains to complexity is this: we shouldn't think of our friends and acquaintances as a good source of information for where to buy transparent goods, since the information that we collect this way is profoundly partial and deeply fragmented; rather, this mix of links comes into its own when the information that we need is complex (*i. e.* it will *only* ever be partial and fragmented) and the potential pay-off—be it in terms of picking the right person, or in terms of not picking the wrong service—is enormous. At this point, the ability to exploit an extended network of rumour and gossip about who or what is 'hot or not' becomes absolutely vital, and the concentration of F2F social activity in a few key sites extends this network's efficiency and searching capacity significantly by encouraging the formation of many weak ties.

What this means for thinking on knowledge generation and space is that focusing solely on the efficiency and routinisation of the 'learning region' is likely to overlook the real value of what happens in particularly innovative milieus (Grabher, 2001, p.371). As we have seen, this is particularly true in the cultural sector where "people need to be in the same place, at the same, time, constantly interacting…in situ and in real-time" (Currid and Williams, 2010, p.2). This review has suggested that the ability to 'bounce' ideas off colleagues or collaborators is universally valuable—though to varying degrees—in all knowledge-related employment, and this helps to explain why knowledge work still tends to be spatially clustered, but not always in the CBD and not always at the densities seen for some cultural and financial activities.

The interdependence between communication and location enables us to shed additional light on Goddard and Pye's insight that relocation from an urban to a non-urban area almost inevitably leads to an alteration of the functioning of the relocated office: established relationships break down because of distance, new relationships emerge but are qualitatively different in nature, and more formal 'contact events' replace spontaneous ones (1977, p.20). As a result, we are left with Goddard and Gillespie's expectation that offices and factories in the North of England, Wales, and Scotland will interact mainly with clusters in the South instead of with one another, and that this will hamper the emergence of a 'local information environment'—a knowledge economy—upon which economic development can be based (1986, p.386).

However, recent advances in computer processing power and storage capacity are finally bringing ideas such as Goddard and Gillespie's within the realm of test-ability: using increasingly fine-grained communications data sets, it is becoming possible to examine these interactions on a grand scale and to determine whether or not the informational flows predicted by the theory are happening in the real world. Having set out in the preceding four chapters to understand the underlying principles of information and knowledge flows, it is now appropriate to turn towards the empirical data that, I hope, will help to move forward the debate on the spatial characteristics of the knowledge economy. But before diving into the data, we first need to properly situate this work within the emerging field of computational social science (CSS) and to establish its relevance to the topic at hand.

6
Methodology

6.1 Introduction

We have seen that the workings of the knowledge economy are bound up in the interactions within and between firms and individuals. However, data on information and knowledge flows extending much beyond the level of the individual case study has been difficult: not only difficult to map, but difficult even to collect. The only widely-available data source on the activities of firms is at the level of sectoral employment, but the Standard Industrial Classification (SIC) data "focusses on [the] outputs, not [the] functions of the office" (Goddard and Pye, 1977, p.298). So there is a basic evidentiary problem in trying to study firms and clusters (Knoben and Oerlemans, 2008, p.386), not least of which is the challenge of trying to collect data for many of them at once (Staber, 2007, p.514).

Fortunately, even as telecommunications is rendering many interactions invisible, it is also making them accessible to researchers on an unprecedented scale. Using telecommunications data supplied by major British and American networks, in Chapter 7 we will be exploring this 'space of flows' to see if telecoms data can augment our ability to understand the socioeconomic structure of cities and city-regions. However, because much of the material and many of the issues raised by the data and the methodology that I employ will be new to readers, Chapter 6 is organised as follows: the first section sets out how we can pursue the original research questions in light of the findings from the literature review; the second section puts the selected methodology in context and identifies some of the key strengths and weaknesses of this approach to urban and regional research; the third considers telecommunications data collection and positions the research within the nascent study of regional- and national-scale networks; and subsequent sections discuss the various steps employed for social, economic, and telecommunications analysis.

6.2 Revisiting the Research Questions

In the course of the past four chapters, we have explored the ways in which locational decisions by firms are impacted by diverse factors: infrastructure availability and flexibility; the relationship between inputs and outputs within and between firms; the dynamics that come into play when many firms colocate in a single location; and, finally, the ways that knowledge-driven work impose new constraints on firms even as information becomes ever less place-bound.

I began this work by setting out four challenges that telecommunications poses for planning; the first of these—the challenge to planning theory—has been addressed in Chapters 2 through 5; it now time to address the second and third challenges: those of invisibility and analysis. In this chapter, we will consider how both of these might be addressed by this, or indeed any other, research rooted in telecommunications data. We will seek to establish the ways in which telecommunications can be made visible, and to set out how we can analyse informational flows in order to better understand their effect on the fourth and final challenge: our conceptions of time and place.

The Picture So Far

Infrastructure & Regions: In Chapter 2, Infrastructure and Regions, we considered the interactions between infrastructure and accessibility. Although the Christallerian concept of 'centrality' proved useful as a foundation for thinking about specialisation and access, we have seen that his central places are no longer—if, indeed, they ever were—defined by the diversity of goods available; instead, they can be identified by the number and type of networks intersecting in space. In a contemporary context, "one of the persistent advantages of urban areas over non-urban ones is the thickness and density of their communication infrastructures and ICT networks" (Athey et al., 2007, p.17).

Subsequent work by Lösch (1954 [1973]) led us to the idea that different sectors might have differing dependencies on infrastructure and that this might, in turn, affect the flexibility with which they could pursue different locational strategies. Using the concept of relative flexibility—as well as the related dimensions of monetary cost, speed, bandwidth, connectivity, integration, and convenience—we were able to get to grips with the basic tradeoffs between travel and communication, addressing an historical gap in planning theory: how to begin comparing radically different infrastructures and types of interaction.

To put this flexibility in more concrete terms, in constant 1996 prices, the cost of a three-minute call from London to New York City has fallen from £486.98 in 1927 to £62.80 in 1945, £12.46 in 1970, and £0.52 in 1996 (Hall, 2003, p.141). For many people, the cost of an international call now borders on the negligible[1], so from the perspective laid out in Chapter 2 this suggests not only that telecommunications will have important effects on the way they interact, but also on how firms perceive this network in relation to other types of infrastructure.

[1] In 2010, the cost of an off-peak call from London to New York on a BT landline without *any* international discount plans is less than £0.30 in 1996 terms, and for a £5.00 per month subscription one could place nearly unlimited calls for free (British Telecommunications plc., 2010).

Firms, Markets & Risk: In Chapter 3, Firms, Markets and Risk, we turned to the nature of the firm and sought to develop the idea that "economically, [the firm] is fiction" (Drucker, 1999, p.114). We began by returning to Weber and the impact of space on how the firm organises its activities, paying particular attention to the ways in which information flows might be modelled within this a framework built around material flows. Hall (2003, p.142) has suggested that, in Weberian terms, concentrated informational inputs might act "…rather like a large ore field yielding a precious metal", but that in such cases, "the raw material and the market are concentrated at the same location" (*ibid.*).

However, the concept of 'ubiquity' suggests that an 'informational ore' would only be one-half of the picture since information seems to behave like a ubiquity as well. To explain this ambiguity, we turned to the nature of markets and considered how the degree of transparency—which is to say the ease with which information on pricing, suitability, and availability can be accessed—affects their spatial extent. Ultimately, this observation led to the conclusion that ICT, by making it easier to seek out pricing data and to interact with suppliers, deterritorialises transparent markets but has only a limited impact in opaque markets.

Furthermore, by adopting a broad view of transactions we could see how "transaction costs and the value of economic information have increased over time as markets have expanded in scope and as economic processes and products have become more complex" (Garcia, 2002, p.47). In particular, we found that Charlot and Duranton's (2006) model of search and execution costs makes it clear that determining the 'right' price for a product or service is a far from trivial operation. Over the course of the chapter we came to see that the flow of inputs and information within and between firms also affects the flexibility with which they can pursue some 'ideal' locational strategy.

AGGLOMERATIONS & CLUSTERS: In Chapter 4, Agglomerations and Clusters, we incorporated the dynamics of life-cycle and scale for products, firms, and industries, as well as the characteristics of environments where many firms colocate. This chapter also reinforced our appreciation of the importance of *instability* in firm operations: I argued that there is an oscillation between stable and unstable configurations, and that the uncertainties embodied in this oscillation encourage specific organisational and spatial responses. Communications and information-processing technologies affect this process by enabling more flexible and complex reconfigurations: one strategic manager for a retail bank reports that "we showed that synergies in banking are not only obtained by closing branches, but also by having a good combined ICT platform…[it] allows you to grow your business without growing the back office in the same proportions" (Economist Intelligence Unit, 2006, p.46).

We then turned to the process of agglomeration and found that it has three important advantages for firms: first, that it enables firms to share the cost of public and private infrastructures, enabling them to out-compete firms in less well-provisioned regions; second, that it improves the 'search and match process' by increasing awareness of, and access to, the local market; and third, that it reduces the cost of managing ongoing complex interactions. These factors become especially important to firms when informational and material flows are intense, unpredictable, and unstandardised.

I then argued that information flows also lie at the root of clustering, but that clusters may well be *inefficient* by traditional measures since they tend to be costly and congested locations. However, the diversity of informational inputs, and the frequency of encounters between competitors and collaborators, in clusters generates crucial long-run benefits, and I find it particularly encouraging that Menzel and Fornahl (2010) have connected the 'sustainability' of clusters to their ability to maintain a delicate balance between 'thematical' (*i. e.* productive and technological) coherence and diversity; the authors suggest even that clusters may oscillate forwards and backwards through various stages of development (*i. e.* life-cycles; see Figure 4.8), and I think that this nicely draws together my arguments on scale, life-cycle, and instability as fundamental factors in clustering.

The Knowledge Economy: In Chapter 5 we turned finally to the knowledge economy, and we found that the distinction between codified and tacit knowledge maps nicely back on to the Weberian distinction between ubiquities and localised inputs. By drawing on the knowledge bases approach (Asheim et al., 2007), we were able to reconcile Storper and Venables's (2002; 2004) basic dichotomy with divergent preferences at the sectoral level: the analytical, synthetic, and symbolic bases all play a role in shaping how knowledge work is done. So although social interaction is a component of *all* knowledge work, what varies with the knowledge base is the extent to which social interaction is an integral element of the generation and transmission process.

We then considered the ways in which knowledge could be exchanged between workers, and highlighted the degree to which face-to-face (f2f) interaction is still integral to this process. Because we are social animals, physical proximity provides more than just massive bandwidth—though this is also important—it stimulates trust, generates motivation amongst participants, streamlines screening processes, and enables complex and uncertain—unspoken, even—knowledge to be shared. This understanding of the value of f2f led to an examination of the ways in which different types of 'proximity' could be deployed to stimulate and support the efficient dispersal of complex knowledge.

Hypothesis Generation

Although the literature review has set out what I believe to be the organising principles of contemporary firm location strategy, it has not clearly set out any testable predictions. So we must take a step *forward* from broad generalisation if we are to advance the analysis substantively. Figure 6.1 draws on the factors identified in the preceding chapter to lay out a tripartite categorisation of 21st Century work. I believe that these three axes can be used as a guide to modelling a firm or sector's spatial decision-making—in each case, the dashed grey line along an axis points towards greater locational flexibility, and the solid black line towards less—and so can be used to predict their distribution and interaction profiles.

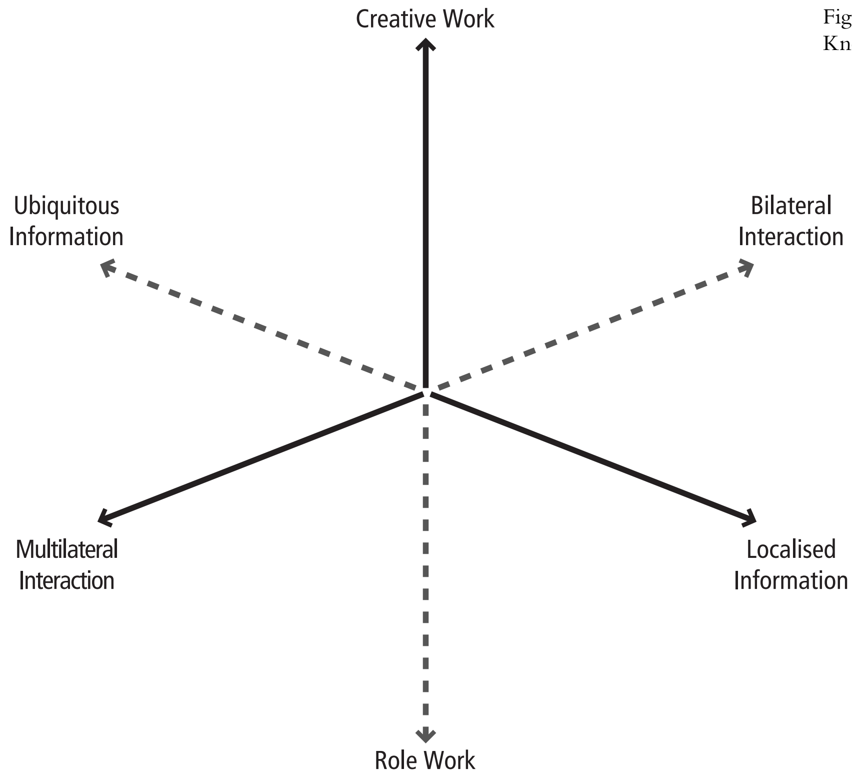


Figure 6.1: Integrated Typology of Knowledge Work

Localised & Ubiquitous Information: Where informational inputs are ubiquitous thanks to ICT-enabled interactions, I expect there to be a lessening of the external dependencies that constrain locational decisions. When workers can access relevant information or knowledge from anywhere, then this makes actual location a relatively less important factor in work. Conversely, where opacity confines key knowledge to a particular local context, then the places and times where such assets to become available will be correspondingly more important.

Multilateral & Bilateral Orientation: Ongoing multilateral interaction—especially of the social forms favoured by symbolic knowledge workers, and of the cross-cutting forms favoured by, for instance, financiers—is prohibitively costly in inaccessible places. Here, the provision of high-density, high-quality infrastructure, especially of the 'upper-tier' type, will tend to bind multilaterally-oriented workers to the very largest urban locations. In contrast, I expect bilaterally-oriented work to be increasingly deterritorialised, especially where interactions are routine or are sustained over long periods of time such that participants build up a shared context to streamlines exchanges.

Creative & Role Orientation: By creative orientation, we should understand any type of work—analytical, synthetic, or symbolic—that involves the generation of new knowledge. Clearly, this axis incorporates a continuum of practices, and so rules-based work falls somewhere in the middle. In much the same way as a network is ultimately constrained by its least flexible links, we can expect to find that some parts of an organisation are constrained by the requirements of its least flexible (or, to put it another way: most desirable) employees, and these are almost invariably the creative workers. However, we should not forget that the complex and collaborative nature of contemporary innovation means that even the most knowledge-intensive workers may depend on a support-structure of skilled technicians and administrators[2].

[2] In fact, Drucker (1999, pp.149–154) makes much of the importance of 'technologists' to America's long-term advantage in productivity. These workers have a great deal in common with my 'rules-based' workers classification, and one of his examples concerns AT&T technicians who were trained in the 'right way' of doing things by the corporation, but were then given substantial latitude in determining how best to handle customer issues (*ibid.*); this is, to my mind, a canonical example of 'rules-based' work which combines a degree of autonomy with predefined execution paths.

Prediction & Empirical Verification

Location & Telecommunication: Using Figure 6.1, we can generate a series of predictions about the spatial distribution and interaction characteristics of different sectors, and even of firms or offices within sectors. The underlying expectation is that, because types of work differ along one or more axes, they will also display systematically different spatial preferences and communicate with others in systematically different ways.

So it is the nature and degree of the similarities and differences that helps us to predict a sector's likely locational decisions. We can summarise these predictions as follows:

1. Localised work will be found near larger transport nodes, while Ubiquitous work will be more dispersed;

2. Creative work will be found in high-amenity areas, while Role work will be found in lower amenity areas; and

3. Multilateral work will be found in areas containing many sectors, while Bilateral work will be found in areas with industrial monocultures.

However, spatial disposition is only one aspect of firm behaviour, and we must also consider how this typology affects predictions of telecommunications usage. This yields three more predictions:

1. Localised work will communicate with fewer areas, while Ubiquitous work will communicate with more;

2. Creative work will employ telecommunications intensively, while Role work will use it less; and

3. Multilateral work will employ telecommunications across smaller areas, while Bilateral work will use it over larger ones.

Globalisation: On top of these underlying differences, we must also superimpose a geography of internationalisation since many of the sectors most closely associated with knowledge-intensive industry are also closely associated with the process of globalisation. There is a widespread presumption that "…globalised economic sectors tend to be intensive users of the new telecommunications and computer technologies…" (Sassen, 2002, p.4), and this implies very strongly that these sectors will have a particularly prominent presence in the telecommunications data.

SECTOR SELECTION: We have examined a number of industries in some detail over the course of the preceding chapters, and so it is appropriate to use these same industries as the basis for the empirical verification of the predictions developed in the literature review. Table 6.1 highlights three overlapping definitions of sectors closely associated with the processes of interest, so by sampling these sectors' spatial and communicational preferences we can see if the evidence stacks up with the theory.

Table 6.1: Sectors Associated with Knowledge Work, Face-to-Face Interaction, and Globalisation

Sector	Pain and Hall (2008, p.1068)	Taylor and Walker (2001, pp.24,25)	McCann (See footnote in 2007, p.132)	Derudder et al. (2010, p.1866)
Accountancy	Y	Y		Y
Advertising	Y	Y		Y
Arts & Theatre			Y	
Finance	Y	Y	Y	Y
Design	Y			
ICT	Y			
Insurance	Y	Y		
Law	Y	Y		Y
Logistics	Y			
Management Consultancy	Y	Y		Y
Political Consultancy			Y	
Publishing			Y	
Real Estate		Y	Y	

Summary

At the intersection between the typology of knowledge work outlined above, and the internationally-oriented businesses identified in Table 6.1, lies a set of concrete practices of location and communication. There will necessarily be variation within each sector, and I fully expect the size and degree of globalisation of each firm to affect the observed behaviours. However, we must nonetheless place some kind of stake in the ground against which to test the theoretical predictions. So although we expect the data to require the refinement of the hypotheses, Table 6.2 serves to anchor the analysis undertaken in Chapter 7.

To test the predictions set out in Table 6.2 we will need two complementary data sets: one which enables us to localise industries, and

Table 6.2: Spatial and Communications Predictions

	Sector	Spatial Preference	Communication Preference
Symbolic	Cultural	Highly-clustered in core cities; high amenity	F2F; local
	Advertising	Highly-clustered; clients accessible	F2F; local & global
Synthetic	Global Finance	Highly-accessible; largest agglomerations (*i. e.* CBD) with specialised labour available	F2F; global
	Engineering	Connected areas; high amenity; specialised labour available	Regional; some global
	APS	Well-connected areas; clients accessible	Regional; some global
Analytical	ICT	Dispersed; high amenity; clients somewhat accessible	Global; some regional
	R&D	Highly-dispersed; high amenity	Global; few external linkages
Flows	Logistics	Highly-connected areas; cheap land & labour	Global; some regional and local

one which enables us to examine their telecommunications usage. Fortunately, industrial employment data is relatively accessible—though, as we will see, it is not without limitations—and the National Online Manpower Information System (NOMIS) provides the relevant data for Britain[3] at a range of geographical scales.

[3] Similar industrial data for America is provided by the U.S. Census Bureau.

Until recently, the second data set of telecommunications has been beyond the reach of academics, but as the next section will make clear, this is now changing in a dramatic fashion thanks to an alignment between computing and storage power, and the increasing willingness of a small number of network operators to make various types of anonymous data available to select individuals and groups. The conjunction of industrial—and, for that matter, residential—and communications data promises to transform the nature of social science research.

6.3 Methodological Context & Concerns

Computational Social Science

Historically, the cost and complexity of capturing large, detailed data sets has meant that much of social science research relied either on small-scale surveys, or on large-scale national studies funded by central government for administrative purposes. The latter programs tend to be mounted decennially at best, and the timeliness of the results is often inversely proportional to the scope of the research. The basic problem here is that the cost of collection increases with the sample size (cf. Pain and Hall, 2008, pp.1069–1070): to double the sample size is, typically, to double the cost of the research; to double the length of the survey is, in all probability, to halve the number of respondents.

However, the increasing mediation of everyday life by digital networks offers a new way to collect data on human populations on a truly massive scale: a single phone company's Call Data Records (CDRs) can shed light on the behaviour of millions of individuals! At that scale we are no longer really even dealing with 'sampling' as traditionally conceived. Researchers are already analysing data sets from network operators in Europe, America, and Africa with a view to understanding the links between such varying characteristics of social existence as individual mobility and commuting, public health and the spreading of epidemics, and the correlation between social network structure and deprivation (cf. Ahas and Mark, 2005; Ratti et al., 2006; Eagle, 2008; Gonzàlez et al., 2008; Eagle et al., 2010).

Lazer et al. (2009) argue that our ability to leverage rich sources of behavioural data is ushering in a "computational social science" (CSS) that is markedly different in scale and scope from existing practices in fields such as sociology or planning. We can also position CSS within the larger category of 'third culture' research that seeks to bring methods from the natural sciences to bear on some of the more intractable problems in the social sciences (Brockman and Williams, 1995). This is not, of course, to suggest that other modes of data collection—such as qualitative interview data—will play no role in future investigations, but rather that they can now be aligned with much larger data sets on what people actually *do*: intention can be tested against action.

The value of the CSS approach is already recognised by business—one employee of Google observed that "we like learning from large, 'noisy' data sets" (Economist, 2010c)—but declining storage and processing costs have finally brought this type of analysis within the reach of academics. Quite simply, "existing ways of conceiving human behaviour were developed without access to terabytes of data describing minute-by-minute interactions and locations of entire populations of individuals" (Lazer et al., 2009, p.722), and as a result this represents an enormous augmentation of our ability to investigate human activity on a grand scale. What also sets CSS apart from other approaches is its reliance on the 'informational exhaust' of contemporary society, which it transforms into a tool with which to analyse society itself[4].

[4] An excellent example of this is the work undertaken by Currid and Williams (2010) using the commercial Getty Images database to map the density of fashion, theatre, and music events in Manhattan and Los Angeles

LaGrangian & Eulerian Approaches

If the study of telecommunications is really a study of informational flows, then we can also position this research within the distinction between LaGrangian and Eulerian analyses. This difference originates in the fact that there are two ways of describing the motion of a fluid: from the frame of reference of a particle in the fluid, and from the frame of reference of a fixed point across which the fluid moves. In more concrete terms, it is the difference between studying a river from a boat floating downstream, and studying a river by watching it from the shore (Wikipedia, 2006). This seemingly esoteric distinction has one very important implication: that there are actually *two* ways of analysing telecommunications flows, only one of which has received much research attention.

From the standpoint of telecommunications, LaGrangian methods—the particle approach—naturally fit the study of individuals. So this mode of analysis seeks to build a picture of the whole from a sampling of its separate parts and, given the particular physics backgrounds of many network scientists, this is naturally the point from which they approach the study of such data. LaGrangian styles of analysis are what gives us Gladwell's (2000) 'hubs', 'mavens', and 'salesmen', and Barabási's (2003) power laws and preferential attachment models.

In contrast, Eulerian methods—the fixed point approach—enable us to get at something subtly different. Let's imagine for a moment that we have one building from which people flow out at 8 a.m. and flow in at 6 p.m., and another building into which people flow at 9 a.m. and out from which they flow at 5 p.m. We know nothing about the individuals going in and out, but we can nonetheless infer that the first building is residential and the second, commercial. If we imagine too that there are several hundreds of people doing so each day, then we might also infer that we are dealing with a major office development or housing block. The point is that the flows—in terms of their timing, direction, and magnitude—tell us a great deal about the location being monitored. In effect, we use the characteristic flows to develop a description of place, and by comparing many spaces simultaneously we can group them according to the degree of similarity expressed in their patterns flow.

Mapping

However, one of the basic challenges of mapping this space of flows is the lack of an appropriate representational tradition: the data itself are new, as is the way that they join non-contiguous places together. There is no natural means of showing this data, and consequently the information-space only adopts "the formal qualities of geographic (Euclidean) space if explicitly programmed to do so" (Dodge and Kitchin, 2001, p.3). What this means is that the mapping of telecommunications is inseparable from a process of 'spatialisation'—the assignment of map-like structure to data without any inherent spatial aspect (2001, p.2)—and, as such, is inherently arbitrary: is it better to map minutes or megabytes? the route taken by the data? or the link that it actually established?

This challenge is made more difficult by the sheer volumes involved: high levels of generalisation and classification are essential to getting to grips with the data, and this inserts an additional interpretative layer between the recorded events and their representation (2001, p.4). To put it more concretely, I could present a map showing the origin and destination of every call made in Britain, but such a map would utterly incomprehensible. Instead, we are forced to make still more choices, imbuing maps with values and judgements about what is and is not worth mapping (2001, p.3). My point is not that this effort is futile—rather, I perceive it to be absolutely vital—but that there are very real choices to be made about what to show, and that there is such a wealth of data here that not even an atlas could do it justice.

Representativity

Although telecommunications data can tell us a great deal about patterns of interaction, we have to recognise that the analysis of individual Call Data Records tells us nothing about the purpose or quality of that communication. There is also a tendency to associate duration of interaction with intensity of interaction: if two people speak on the phone for twenty minutes then this is somehow a more meaningful conversation than one that lasts five minutes. But duration and frequency interact in complex ways: we seem to call those close to us more often, but speak with them for less time; and to call those who are more geographically distant less often, but talk for longer (Wellman and Tindall, 1993).

Calling data will obviously capture a blend of personal and professional communications (Pain and Hall, 2008, p.1070). Most parts of most major cities contain a mix of activities, and Lee et al. (2007, p.416) have suggested that our phone communications "tend to straddle rather than follow traditional economic, political, and cultural fault lines." However, in the context of the chapters on clustering and the knowledge economy, and of the importance that we were able to attach to social interaction as a business development process, we can see that perhaps our inability to untangle the two types of messages is rather less important than commonly thought. We can also, as we will see in Section 6.6 (see page 235), use employment data to narrow our focus to areas that are more likely to capture economic interactions than personal ones.

Modifiable Areal Unit

A final analytical issue worth noting is that of the 'modifiable areal unit problem', usually referred to by the acronym MAUP. This issue is a longstanding one in spatial analysis: Openshaw (1984) traces it as far back as the 1930s, but it has become a much more pressing concern with the spread of Geographic Information Systems (GIS) and increased use of census-type data for areal analysis. The MAUP was summarised by Dodge and Kitchin (2001, p.5) as "the same data mapped onto differing sets of spatial units (*e.g.* wards, districts, counties, states) can produce significantly different spatial patterns…" In short, the MAUP tends to manifest itself through changes in the relationship between variables at different scales; consequently, attempts to adjust the resolution of the data (whether for abstraction or specification purposes) can lead analysts to draw incorrect conclusions regarding the relationships within and between objects in space (Dark and Bram, 2007, p.472).

Typically, the MAUP can be understood in terms of two dimensions: scale and zone. The scale problem results from the fact that application of data—especially individual or household data—collected at one scale to a different spatial scale can obscure important variations within and between areas. For instance, aggregation will tend to 'flatten' differences by lumping together dichotomous individuals or households into a blander average population (Openshaw, 1984, p.20), with the concomitant risk of increasing correlation between unrelated variables (Fotheringham and Wong, 1991, pp.1033–1038). Conversely, disaggregation will tend to increase random and inexplicable noise in a model or analysis as this smoothing effect is lost (Openshaw, 1984, p.26).

The zoning issue arises when choosing which units to group together into a larger unit: different grouping choices can yield markedly different aggregate results. Fotheringham and Wong (1991, pp.1038–1041) explore this issue in some depth, and demonstrate that various types of re-zoning can cause explanatory variables to swing wildly between significant positive and negative correlations! The net result is that different, and often contradictory, interpretations can be derived from the *same data* depending on the scale at which it is examined or the way in which the data was aggregated.

Certainly, the MAUP is a potential factor in this work, although I have taken steps to limit its possible impact. The underlying issue is that, as with the census (1991, p.1042), confidentiality is a serious concern with such data and so 'individual' callers cannot be the level of analysis. Moreover, there is no basic spatial unit (*bsu*) below the telecommunications 'area'—known in America as the Common Language Location Identifier (CLLI) and in Britain as the Public Exchange Area (PXA), of which more later—that is available to researchers outside of the partner firms and so it is pointless to frame this in terms of 'individual' behaviour or attributes (*ibid.*).

However, the CLLI and PXA are *not* arbitrary areal units: although the social and economic characteristics of each *bsu* may vary significantly, together with their particular usage patterns, they are all designed to provide consistent telecommunications service levels to users within that area. In that sense, these areal units are associated with specific properties and this may go some distance towards moderating the impact of the MAUP. In addition, I have worked with the network operators to join socioeconomic data to this *bsu* in as uniform and reliable a manner as possible, and so treating each of these areas as being of 'unit importance' is the natural, and indeed only, solution.

Finally I have, wherever possible, employed a data-driven classification of space, rather than a hierarchical or user-specified one, and this should help to reduce the risk of MAUP-related problems in the analysis. Fortunately, improvements in computational power in the past decade mean that even quite large spatial data sets can be explored without aggregating beyond the original *bsu*-level; this ensures that, as much as possible, neither zonal nor scalar issues affect the subsequent analysis. Nonetheless, we should refrain from attributing the results extracted from the British and American data sets to the behaviour of *individual* firms within those area; rather, we should interpret these results as reflecting the *environment*—the behavioural characteristics of an area—in which a given set of firms in an area operate.

Privacy

Two of the most impressive pieces of research based on telecommunications network data published to-date examined individual human mobility patterns (Gonzàlez et al., 2008) and the characteristics of social ties between individual users of mobile phones (Onnela et al., 2007). Compared to previous studies, this research represents a massive step forward, but in both cases the results are affected by an inability to compare the results with standard data sets that currently represent the 'gold standard' in place-based research. The consequences of this sensitivity are severe: without even the name of country involved in the research we cannot speculate on the extent to which the results might be culturally-contingent or representative of 'normal' behaviour.

The situation suggests that the data supplier perceived a significant level of reputational and privacy-related risk in supporting this type of research; similar issues affect nearly all of the methodologies documented here—including my own—because the operators reasonably require strict confidentiality agreements and the researchers are eager to protect the advantages flowing from what can amount to years of relationship-building with the analysts and managers of a corporation. Fortunately for my work, both networks involved in this research have been willing to assist me in connecting the electronic geography of communications to a real geography of places, with tangible benefits that I hope to make clear in the course of my analysis.

It is far beyond the scope of this work to argue for, or to develop, a comprehensive data-sharing and liability model, but I would like to note that there are two broad responses to the issue of individual and corporate privacy: the first is philosophical, and the second, procedural. As Lazer et al. (2009) argue, the potential benefits to society as a whole from computational social science (CSS) research are substantial: whether it is using airline and social network data to model a pandemic, or using communications data to understand how groups gain access to information on economic opportunity, social assistance, and health care issues. Consequently, there is a strong case to be made for more enlightened regulation, together with more research into whether and how such data could be shared in a constructive way without compromising the supplier or leaving them open to severe legal liability.

We can also consider how computational approaches can be used to mask individual identity while still granting insight into a group's aggregate behaviours. There is an extensive, but still growing, literature on privacy-preserving database mining; the solutions range from encryption and suppression, to conflation and randomisation (see Reades, 2010 for a summary of relevant techniques). In addition, corporate/academic workflows can be designed so that individually-identifiable data are never shared between research partners in the first place, an option that will be discussed in more detail below (see page 226). We are at a point where data *are* leaking out of sensitive data silos—sometimes with disastrous results in spite of the best of intentions (cf. Sweeney, 2001)—but as yet there is no common framework for negotiating the line between behavioural insight and privacy invasion (Langheinrich, 2002).

Summary

The challenges raised in this section are significant, but they are principally the result of a concerted push by researchers into *terra incognita*. I am not suggesting that such research will supplant existing qualitative methods, but it is worth noting that we will be looking at a month's worth of data generated by the aggregate activity of more than 70 *million* people, and that we will be able to examine in unprecedented detail local and global patterns, regardless of whether these massive flows are headed down the street or to the other side of the planet. As these issues are addressed in a systematic way, then the impact on social science and public policy from CSS research has the capacity to be truly revolutionary.

6.4 Mapping the 'Space of Flows'

Returning now to the challenges of mapping regional and international fluxes, Pain and Hall (2008, p.1069) have pointed out that while secondary data such as the census are suitable for the study of Castells' 'space of places', a different strategy is required for mapping the 'space of flows'. And Taylor and Hoyler (2000, p.179) have pointed out that traditional approaches to regional analysis are premised on the collection and labelling of attributes, when what is really needed is a relational analysis of linkages. In short, a new set of tools and data seem required in urban and regional research.

The phone system addresses both of these issues: the numbers (or their anonymised equivalent) are both universally routable and unique, and they enable us to connect calls to households and businesses for socioeconomic analyses. For the purposes of geodemographic analysis, this means that there are some very substantial incentives to use the phone network as a research platform. The review presented here covers a mix of approaches in order to provide a sense of the directions in which this type of study can be taken; however, many of these projects were conducted with very different research objectives in mind and thus did not logically form part of the literature review in Chapters 2 through 5, where we focussed on the relationship between telecommunications and firms.

Infrastructure Mapping

It can be easy to assume that telecommunications infrastructure is 'as ethereal and virtual' as the data that it carries (Dodge and Kitchin, 2001, p.10); however, as we saw in Chapter 2, the topology of an infrastructure can offer substantial insight into the distribution of activity. Moss and Townsend (2000) and Townsend (2001) use the evolution of bandwidth capacity and peering points on the Internet backbone to posit a shift in the dynamics of urban growth from the primate cities—New York, Los Angeles, and Chicago—towards a second tier that includes San Francisco, San Jose, and Washington, D.C.

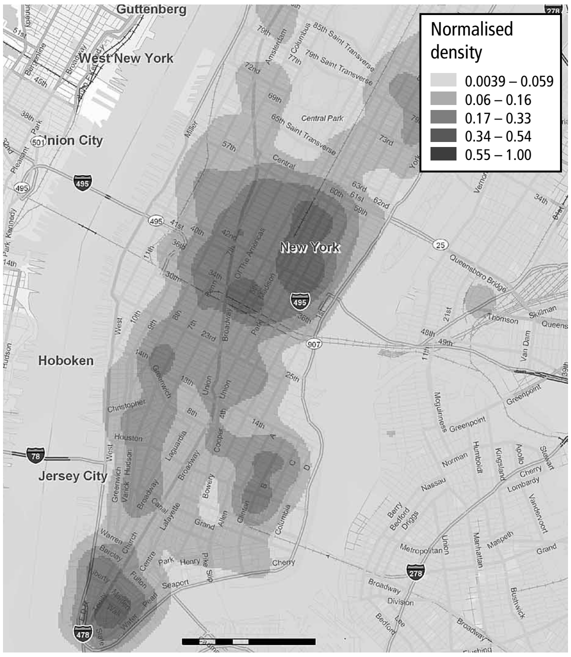


Figure 6.2: Cell phone antenna densities in Manhattan (Shoval, 2007, p.193; reproduced with permission of the author)

In a similar way, Shoval (2007, p.172) argues that the distribution of mobile phone masts can be used to infer the location of urban 'activity-nodes'. Shoval's unusual approach avoids the access issues associated with other methods of phone-based research. Rather than negotiate access with networks or pay a group of volunteers to collect data on his behalf, Shoval used information contained in mandatory regulatory disclosures to map the distribution of towers. Shoval took this distribution as a proxy for the density of human activity (see Figure 6.2), but there are obvious methodological concerns with this approach: in particular, the idea that cellular infrastructure is systematically correlated with some unspecified definition of 'activity'.

The most extensive analysis to date at the metropolitan scale, by Gorman and McIntee (2003), suggests only that the density of Personal Communications Services (PCS) masts for mobile data and voice connections tracks the overall population of American metro regions, and not the distribution of 'activity' within them. In fact, Gorman and McIntee's work (2003, p.1164) indicates that, while wireless infrastructure is more evenly distributed that wired infrastructure, there remains a systemic bias in provision towards large metro areas: they are over-represented on a *per capita* basis across all high-end telecoms infrastructures. Regardless, this creative technique is an important alternative research tool since it avoids the significant challenges facing those who need to work through the regulators and operators.

A third infrastructural approach—using Internet Protocol (IP) addresses—has two technical drawbacks: the first is that there is a weak relationship between IP addresses and physical location (cf. Hall and Pain, 2006); the second is that a great deal of internet usage is migrating on to private networks that use non-geographical addressing. So in the first case, not only can the IP addresses assigned by an access provider be re-used for users in a different physical location at any time, but it is also difficult to localise users at much more than a regional level. And secondly, especially with the arrival of the mobile Internet, traffic is shifting on to the 'walled garden' networks where address blocks cover an entire country and are much less easily probed by researchers.

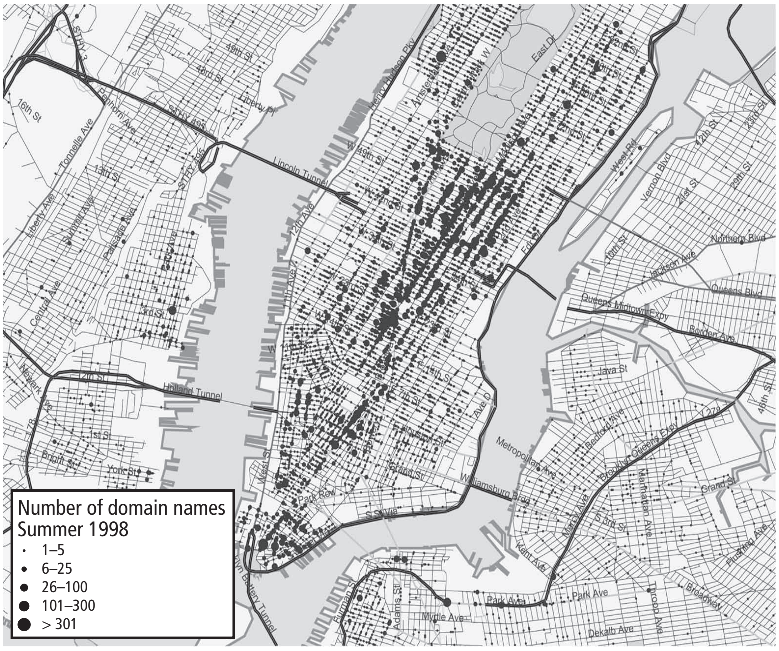


Figure 6.3: Location of commercial domain names in downtown New York (Zook, 2000, p.419; reproduced with permission of Pion Limited)

Finally, in some rare cases the architecture of the network offers a fourth way to extract information about the distribution of activity: Moss and Townsend (1997) and Zook (2000, 2004) have investigated the distribution of domain name registrations as a way of assessing the growth of Internet-related activity at the intra-urban scale (see Figure 6.3). Although this is a clever approach, there are important underlying assumptions: that the location of the registration is functionally equivalent to that of the business; and that the scale of the businesses is consistent or irrelevant. While small firms are likely to register their business address, the same is not true for the vastly larger MNEs: they could register a head office, a back office, or even the offices of the firm's counsel, and we have *no* way of determining which is which without a great deal of manual cleaning[5].

[5] I would also like to note that we should not assume that a popular Top-Level Domain (TLD) like 'dot.com' will only be used to indicate commercial activity. As a resident of New York between 1997 and 2002, and as the owner owner of a dot.com address that I use for personal communications, my own registration is included in the map shown in Figure 6.3.

Handset Mapping

An alternative strategy to mapping the topology of the networks themselves is to map the activities of users of those infrastructures. Eagle and

Pentland (2006; 2009; and see also Barabási, 2010, pp.193–195 for a good summary of this research) pioneered the 'reality mining' approach using an application installed on participants' mobile phones. Running on Nokia handsets, the *Context* application samples the local radio frequency (RF) environment—specifically, the cell towers and Bluetooth devices 'visible' to the phone—and then logs the results as a set of time-stamped observations. Because the devices and infrastructure accessible by the phone vary with geographical location, the phone can use these as a kind of spatial fingerprint and can assign each one to a unique point in space.

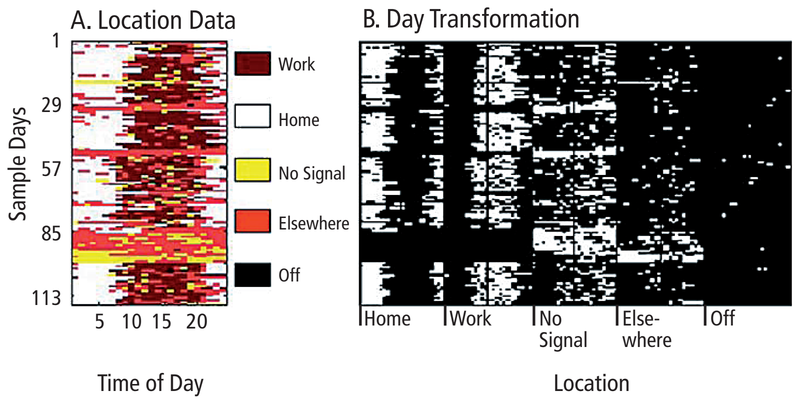


Figure 6.4: Transformation of Location Data in Eigenbehaviours (Eagle and Pentland, 2009, p.1060; reproduced with permission of the authors)

Eagle and Pentland grouped the set of points into five categories: home, work, other, no signal, and off. This classification process yields the simple colour-coded matrix shown in Figure 6.4A, and has the effect of radically reducing the complexity of the ensuing analysis. Now, because a user's position can be represented with just five states, we can simply extend the matrix right-wards so that the first 24 columns hold binary values (*i. e.* on or off) for home, the next 24 columns hold on/off values for work, and so forth (see Figure 6.4B).

Each row represents one day of the total sample collected for that individual and means that Eagle and Pentland have been able to extract a covariance matrix suitable for quantitative analysis from a very 'noisy' environment. In effect, the matrix describes a multi-dimensional behaviour-space amenable to eigendecomposition—this technique will be discussed at some length later in this chapter—which can be used to extract the principal components (most common recurring patterns) of a user's behaviour and discriminate between different types of user. Plotting the components' coefficients in 3D space makes visible distinct groupings within the volunteer sample.

A very different approach is used by Ahas and Mark (2005), who employ network positioning events—usually billable customer actions (see explanations in Ahas et al., 2008a, p.472 and Ahas et al., 2010b, pp.4–5)—to locate customers at the cell-level within the operator's mobile network. Depending on whether they are using active or passive positioning, and whether or not the users being tracked are volunteers, the researchers have different amounts of knowledge about their subjects. Their more complex 'Social Positioning Method' (SPM) analyses merge demographic data supplied by participants with pay-per-position updates from Estonia's largest operator to explore individual mobility patterns at the national scale (cf. Ahas et al., 2008b, 2010a).

Although Ahas and Mark's studies are not constrained by the need to install applications on to a participant's handset, the cost of paying an operator for location updates can be substantial. It is not clear to me if they are still paying for positioning events or if they are now receiving these data in bulk after having built a more extensive relationship with the operator. However, it is certain that the cost of their early collection attempts were prohibitive for long-term research, and so most other research in this area has focussed on collaborating directly with network operators able to supply more extensive data on their entire subscriber population in one go (cf. Gonzàlez et al., 2008).

Aggregate Network Mapping

Difficulties in collecting and analysing aggregate phone data mean that progress in this area has been fitful: one of the earliest papers to examine aggregate point-to-point informational flows on the phone network with a view to exploring regional economic interactions dates from 1979[6]; however, there has been little further research into this area until quite recently. And in the meantime, there has been a seismic shift in both platform and extent: Davies' research used only long-distance calling within the state of Montana, whereas contemporary research has drawn much more heavily on mobile telecommunications, particularly from Italy (cf. Ratti et al., 2006; Reades et al., 2007), and has used fine-grained data with temporal resolutions as high as 15 minutes and spatial resolutions measured in tens of metres.

[6] There was, however, earlier work rooted in the 'social physics' approach; Stewart, 1950, for example, considers the flow of bank cheques to and from New York in light of rank-size laws and population potentials.

Ratti et al. (2006, pp.740–744) used heat maps to identify activity hotspots on the mobile network, but also put forward the idea that the usage levels of a cell generate a unique 'signature' that is related to the activities taking place within its coverage area. Variations in mobile bandwidth usage—measured in Erlang—can be used to "infer information about the 'character' of a neighbourhood in which the antenna is placed" (2006, p.740). To put it simply, an antenna with higher usage between the hours of 9 a.m. and 5 p.m. would most likely be providing coverage in a work/office area, while one with higher usage before 9 a.m. and after 6 p.m. would be located in a residential neighbourhood (see Figure 6.5).

However, the nature of phone networks means that some infrastructure carries thousands of simultaneous calls, while other hardware may have just a few connections for most of the day. To enable such wildly varying levels of usage to be compared in some meaningful way, Ratti et al. (2006) suggest that two forms of normalisation are necessary: first, a 'normalisation in space' in which each antenna's load is normalised against the total load on the system at a single point in time; and second, a 'normalisation in time' dividing the load on an antenna at a given point in time by the average load on that antenna for the entire day.

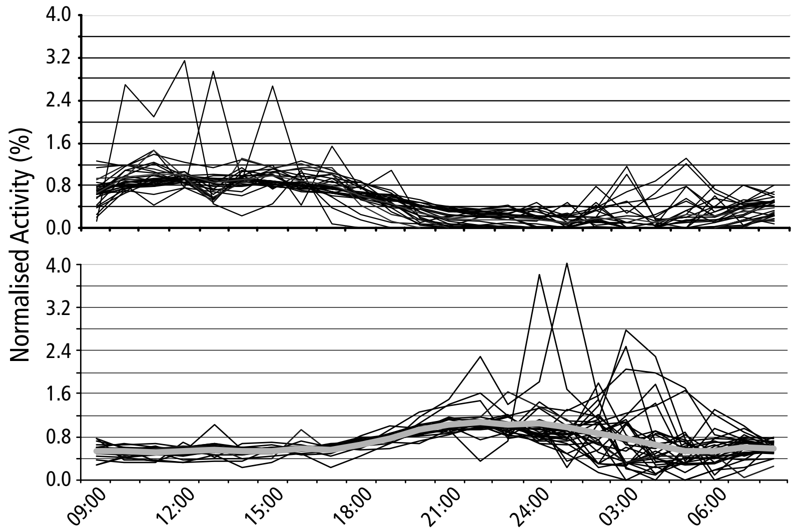


Figure 6.5: Cell activity—a group of cells with prevalence of activity during (a) office hours, and (b) the evening and night time (Ratti et al., 2006, p.741; reproduced with permission of Pion Limited)

Normalisation in space allows us to control for the fact that usage levels are globally lower at 1 a.m. than they are at 5 p.m., while normalisation in time allows us to control for the fact that city-centre infrastructure *always* carries more traffic than suburban or peripheral infrastructure.

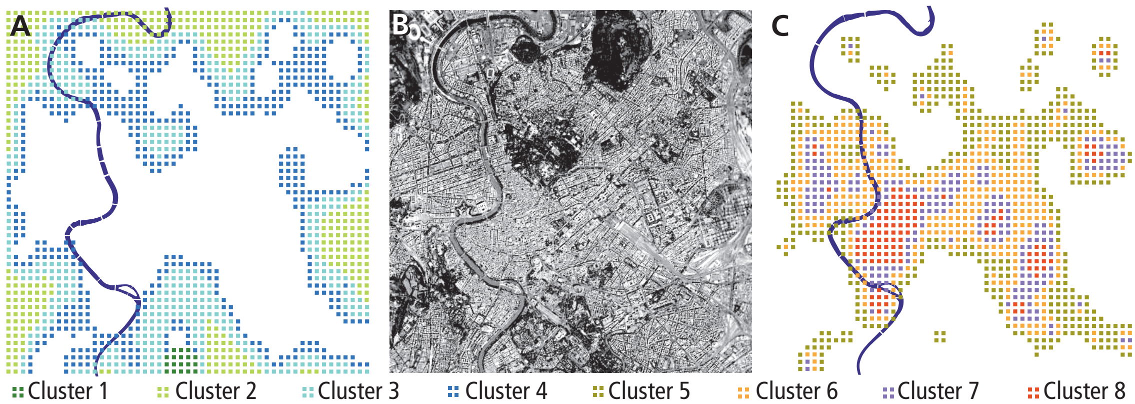


Figure 6.6: Analysis of eight clusters of Erlang data: (a) clusters 1–4; (b) a satellite view of Rome, for comparison; (c) clusters 5–8 (Reades et al., 2007, p.36)

Signature analysis was extended by Reades et al. (2007) to address the fact that hundreds, or hundreds of thousands of unique signatures simply cannot be analysed by hand. This work was the first to try to apply clustering to the study of aggregate telecommunications usage, and the technique employed in this article was fairly straightforward: the researchers identified six times of day when usage varied substantially from place to place and then used these data points to create a multi-dimensional vector that could be fed into a k-Means clustering algorithm. Clustering grouped the spaces according to their degree of similarity across the six observations, and in Figure 6.6 we can see how some clusters (*e.g.* 2 and 3) picked up non-urban features such as parkland and lower-density building, while other clusters (*e.g.* 7 and 8) identified high-flow zones such as the Termini rail station and nighttime activity hotspots spanning the Tiber.

For our purposes, however, perhaps the most interesting mapping effort to-date is that undertaken by Halbert (2004, 2008) for the Île-de-France region. Halbert is explicitly trying to connect telecommunications flows to informational flows between advanced business and provider services (APSs) and other classes of business (see Figure 6.7). Unfortunately, there are aspects of Halbert's analysis that are puzzling and, ultimately, rather frustrating: while some maps appear not to have controlled for population at all (cf. Halbert, 2004, p.224), other maps speak of a 'positive residual' for inter-regional telecommunications (cf. Halbert, 2004, pp.230–231), although the formula for calculating these residuals seems incomplete (cf. Halbert, 2004, p.89).

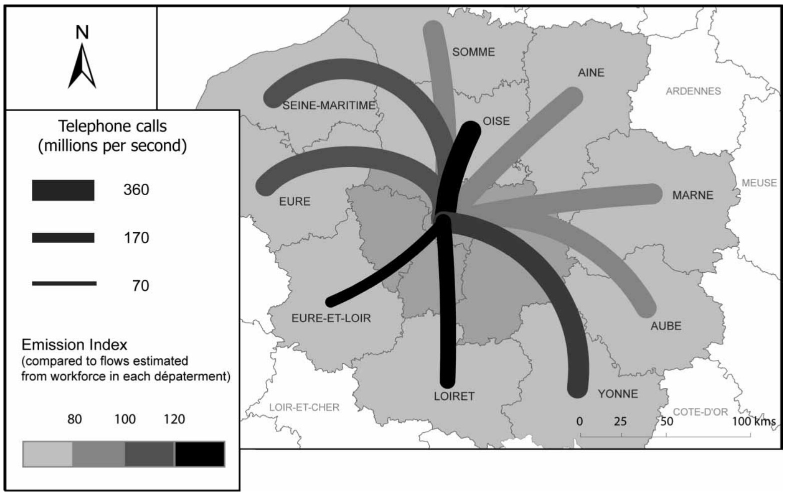


Figure 6.7: Calls in the Paris MCR Region (Halbert, 2008, p.1157; used with permission of Taylor & Francis)

Summary

Clearly, researchers are pursuing a wildly divergent set of strategies for mapping informational flows and the intensity of information-driven activities. This is, at least in part, simply a reflection of the diversity of data sets to which academics are gaining access, but it also reflects a growing sophistication in approaches to these very large, very complex data sources. My own work is firmly positioned within the aggregate research tradition established by Davies (1979) and taken up by Ratti et al. (2006); I feel that handling the data in this way offers the best way to measure the structural flows which define an informational region, and also carries the lowest risk of privacy pitfalls because unaggregated records are discarded at the earliest opportunity.

6.5 Data Provision

The findings in Chapter 7 will focus on data drawn from Great Britain because it proved to have a scope and resolution that enabled me to advance my research much further; however, where the need arises to illustrate a key point in the text I will also present results drawn from New York City. The U.K. data contains information on a majority of landline calls made in August 2005, while the American data contains calling information about mobile, leased-line, and fixed-line calls in September 2008. For brevity's sake I have highlighted only the most relevant aspects of the data sets below, and more detail on the data, record layouts, and relative merits of both data sets is available in Appendix D: Data Management & Processing, beginning on page 477.

About the Research Collaboration

Access to both data sets was initially arranged through M.I.T.'s SENSEable City Laboratory, to whom I owe an enormous debt of gratitude for their support. The research was designed simultaneously to allow academic research into local and global connection patterns, and to help the operators to understand the environmental and contextual drivers of network usage. Unlike some providers of network services, both operators are typically constrained by regulation to engage primarily in research that will help the firm to improve service delivery to end-users; this treatment sets up a difficult dynamic that will need to be addressed in the long term if public interest research is to progress.

About the Operators: For complex reasons, neither the British nor the American operators are able to be directly named and thanked for their involvement in this research, but it is nonetheless important to give a sense of their market position and services so that the reader can form a picture of the representativity and scale of the data employed in the analysis. The major American telecommunications company offers mobile, wireline, and broadband services, but the geographical distribution of these offerings is not uniform: consumer services are of limited availability in New York, while business-oriented services for large companies and public bodies are offered across the United States. Similarly, the U.K. operator offers a wide range of services to households and major corporations and institutions on a national scale, but its principal focus is fixed line operations.

Data on market-share is difficult to come by for more recent years, but as of 2004 the American telecommunications company accounted for approximately one quarter of all U.S. billed minutes (Federal Communications Commission, 2009), and it remains one of the largest American networks today. However, a long-term strategic shift in focus away from consumer services towards integrated voice and data products targeted at the global enterprise market means that the operator has particularly good coverage of large businesses, even in areas where it is not an incumbent. This makes the carrier an excellent partner for research into the spatiotemporal aspects of telecoms usage by businesses, but it does also imply that care must be taken when drawing conclusions from research undertaken in areas—such as New York—that are not part of the operator's 'home territory'.

Similarly, in 2005—the year from which the data is drawn—the British operator was amongst the country's largest providers of telecommunications services to homes and businesses (Ofcom, 2006). Using data drawn from regulatory filings, it is possible to infer that in that year the operator accounted for approximately 75% of all fixed business and residential connections. Given the intensity of competition in the British market, this represents astonishingly complete coverage of the country's calling activity. In short, the sheer scale of both carriers' operations ensure that micro-scale differences amongst customers are unlikely to systematically bias the analyses in ways that will fundamentally invalidate the findings.

Terminology

Before delving more deeply into the data provided, it will be helpful to review the terminology in use in both markets since much of it will be entirely new and potentially rather mysterious. This brief overview is supplemented by more extensive material in Appendix D: Data Management & Processing on page 477.

North America: North America utilises a standardised naming and addressing scheme—an eleven-character Common Language Location Identifier (clli, pronounced 'silly') code—that was created to enable network hardware to be uniquely identified. The relationship between a clli and a phone number is complex because number portability and physical mobility mean that the number may no longer be near the region suggested by its area code.

It may be helpful to think of clli codes as analogous to ip address blocks and phone numbers as analogous to human-readable urls. In other words, many phone numbers can be associated to a single clli, and it is (at least in theory) possible for a number to reallocated to a new clli should the need arise. So the number identifies the intended recipient of a call, at which point the network uses cllis to route the call to an actual location. Because of its historical role in billing and maintenance systems, clli-level data is relatively easy to collect for a network operator.

Great Britain: The basic spatial unit for British landline data is the exchange area: this is conceptually similar to a wire centre in that it corresponds in some way to a geographic service area for handling wireline calls. One exchange area may contain several independent network switches, but the data is only reported at the exchange area level. Because the U.K. has limited number portability—it is available for mobile phones, but is much more tightly circumscribed for landlines—there is little difference between the number and its routing. In short, all numbers beginning 0207–722 would be sent to North London and never, say, to Aberdeen; only the 0800- and 0845-class of numbers lack a geographical mapping. The typical British exchange is rather smaller in size than an American clli, giving it a higher spatial resolution and allowing the data to be used for more detailed studies of activity, especially in urban areas where the exchanges can be quite tiny.

Other Countries: Beyond Britain and North America there are many different standards for phone numbers and routing, so only rarely can the number be used to predict the final destination of a call. For instance, data on calls to France suggest the existence of no less than 15 'sub-regions' in the Île-de-France area; however, it is impossible to determine which, if any, of these subregions map on to the urban heart of Paris or on to business centres such as La Défence. In fact, the only consistent part of any number is the mandatory country code and so, following discussions with the networks, it was agreed that international calling data should be mainly handled at the country-level.

Overview of Data Sets

North America: The data for nyc amounted to some 10gb of raw data: for each hour of each day we received a count of the total number of new calls and total time spent on all calls, grouped by New York clli and by remote location, of which there are approximately 32,000. We also know whether the call originated or terminated in New York, the platform on which the call originated, the latitude and longitude of the New York clli, and as much information as the network operator was able to infer about the counterparty's general geographic location[7].

A simplified version of three raw records is shown here:

```
20080901,0,Dedicated,Terminating,NYCXNYTRDS1,40,-72,Bronx,
              APNUNK,US,No_state,,1,1.5
20080903,13,Pre-Paid Card,Originating,NYCMNY371MD,40,-72,Manhattan,
              5922,GY,,Georgetown,1,4.3
20080911,23,Voice-over-IP,Originating,NYCQNYCODSO,40,-72,Queens,
              9144,IN,,Chennai (Madras),1,0.0
```

Reading from left-to-right, each record shows: the date, the hour of the day, the platform[8], the direction, the New York clli, the latitude and longitude (here masked for security reasons), the borough in which the clli is located; then, there is the remote location identifier (often a clli if the call is within North America), its two-character iso country-code, its state name and city name, and finally, the number of calls and number of minutes. Because of New York's enormous telecommunications volumes and the number of permutations of these different dimensions, the total number of records transferred exceeded 100 million rows.

Figure 6.8 shows the distribution of cllis across the five boroughs, and I have provided an inset for lower-Manhattan because the sheer density of infrastructure there would otherwise make this map illegible. Note that here we are distinguishing between two types of cllis: wire centres, and all others. The 66 wire centres field fixed line communications and so have a specific geography to which measurable demographic attributes can be attached; they thus form a bridge between the geography of communications and the geography of people and firms. The boundaries of the wire centres were used to group the appropriate U.S. census tracts into each clli. The same is not possible with the mobile and private branch exchange (pbx) switches (represented by the light-grey marks in this figure) because the coverage area (*i. e.* cell) of a

[7] Local calls were not included, though there are some cases where local calls were accidentally captured by the collection process. This data was suppressed from my analysis as it is not representative of intra-urban flows.

[8] It should also be noted that this data highlights the ongoing relevance of this type of analysis for the future since Voice-over-IP data—as long as it is not generated by user-level applications such as Skype—can also be researched this way.

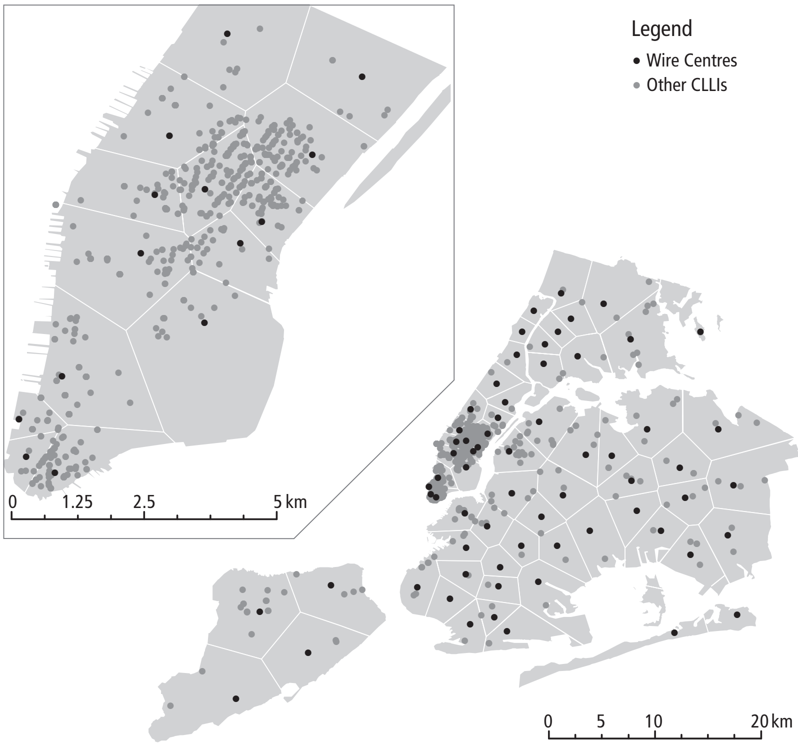


Figure 6.8: Mapping CLLIs on to Wire Centres in New York City

particular mobile tower may span the boundary of one more statistical units—and can even vary over time with local network load—while the PBX may be so specific as to be a potential source of privacy concerns even though there is no corresponding statistical unit with which it can be paired.

In order to build a total telecommunications profile for each area, all CLLIs—regardless of the type of traffic that they handle—had their calls and minutes mapped on to the closest wire centre areas using a Voronoi plot as an approximation (these are the white-edged polygons in the background of Figure 6.8). The Voronoi plot[9] divides space so that the boundaries between service areas are equidistant from the nearest wire centres. Since this process ignores physical geography, some subsequent editing was required to remove artefacts such as islands divided between two CLLIs when one is on the mainland, but by using this plot we could quickly assign every CLLI to its nearest wire centre sibling.

[9] Created in ESRI's ArcGIS using the 'Create Thiessen Polygons' function in the 'Analysis' toolbox.

	Manhattan	Queens	Brooklyn	The Bronx	Staten Island	All Wire Centres
Resident Population (2007 estimates)	1,613,496	2,135,429	2,617,630	1,376,419	478,285	8,221,259
Working Population	2,543,910	646,681	727,191	383,889	147,586	4,449,257
CLLI Count	758	80	72	25	27	962
Wire Centre Count	20	16	18	9	4	66

Table 6.3: Borough Infrastructure Overview

As Table 6.3 shows, there are more than 900 CLLIs spread across the New York-metro area, but the amount of equipment varies substantially from borough to borough: Staten Island contains fewer than

50 switches, while Manhattan contains well over 500. Clearly, with this level of aggregation it is impossible to identify individuals or firms within the data set, guaranteeing the privacy of the operator's customers while enabling researchers to extract significant information from overall telecoms usage patterns. The density of CLLIs in Manhattan is particularly fortunate since that is also where we will find the highest density of businesses. The sheer concentration of telecommunications infrastructure in lower Manhattan, and especially in Mid-Town and around Wall Street, is mind-boggling. For a more detailed breakdown of the infrastructure please see Table 12.2 in Appendix D: Data Management & Processing on page 478.

Great Britain: The very different data set for Britain was collected in August of 2005, and the core table in the SENSEable data warehouse contains 7.2 billion unique records, spanning more than 150GB of data. To date, this is the largest network data set ever made available to academic researchers; the only comparable one from which papers have been published draws on Instant Messaging (IM) data collected by Microsoft's own analysts using its proprietary MSN network (Leskovec and Horvitz, 2008). This massive data set provides a record of nearly every call that either originated or terminated at a landline in the U.K. that month.

Since the data was provided at a finer level, extensive discussions were held with the British telecommunications company to determine the best way to manage the privacy issues associated with the analysis of this data. Each number in the CDR log was assigned a random, unique identifier (*i.e.* a pseudonym, see Pfitzmann et al., 2001) using an approach that would, very deliberately, *never* be shared with us. Following conversion, the data was transferred on a biometrically-secured hard drive to M.I.T., where it was loaded into a secure database using the structure described by the Entity Relationship Diagram (ERD) in Appendix D: Data Management & Processing (see page 481).

A simplified version of the data contained in the core calling table is shown here:

46947334	93164513	2	1	2	26	18	74.00	1
37500942	30778385	1	1	9	25	47	3.00	1
73311732	123904475	3	1	8	23	38	42.00	1
37640164	35791306	1	1	9	19	29	91.00	1
34216069	103654151	2	1	9	4	7	48.00	1

Reading from left-to-right, we have the originating pseudonym (who placed the call), the terminating pseudonym (who received the call), a call-type identifier (*e.g.* landline, mobile, international), a date id, hour id, minute number, seconds number, the duration of the call (in seconds), and the call count (always '1' here because this is a dummy variable). Note that the call-type identifier is determined by whichever of the numbers (if any) is not on a landline because it is only the fixed line that we can localise; so, if both callers are on landlines then the value is 'landline', but if one of the callers is on a mobile then the value is 'mobile', and if one of the callers is calling from abroad then the value is 'international'. The last two options are non-geographic (*i.e.* 0845-

and 0800- numbers) and other (anything not fitting into the other categories).

For calls involving mobile numbers, non-geographic numbers, and international numbers, callers are impossible to localise below the level of the country: for instance, U.K. mobile users could only be identified as calling from somewhere within the U.K., while international callers could only be recognised as having called from a given country. This means that pseudonyms come from a pool of tens of millions and that there is no possibility of reidentification. For the landline callers the situation is more complex: because their location is reported at the level of the exchange there would be a *theoretical* risk of privacy attacks involving the caller's social network if we were not careful handling the data (cf. Backstrom et al., 2007; Bonneau et al., 2009).

Generally speaking, this issue is referred to by privacy researchers as a k-anonymity issue (cf. Sweeney, 2001, 2002a). The simplest solution to k-anonymity risks is generalisation (i.e. aggregation, see Sweeney, 2002b), and here the structure of the data works very much in our favour: the smallest exchange contains a population of nearly 1,000 and covers an area of 19km^2, and the average exchange contains a population of 14,000 within an average area of 36km^2, meaning that it is effectively impossible to disambiguate callers. Furthermore, analysis is conducted entirely at the aggregated level and so individually-identifiable data never leaves the hardened data warehouse.

	Entire U.K.	England	Greater South East of England	Outer Metropolitan Area	Greater London
Population (Mid-year 2005 estimates)	53,431,744	50,451,657	21,410,906	13,492,054	12,103,387
Output Area Count	N/A	32,700	13,600	8,600	7,600
PXA Count	5,600	3,600	1,400	500	400
Average population per PXA	N/A	14,000	15,700	25,600	26,500
Average phones per PXA	6,400	8,300	10,200	17,300	18,100

Table 6.4: British Infrastructure Overview

Since we are here working only with fixed-line data, the data is already mapped on to the relevant 'wire centres'. However, exchange areas do not map cleanly on to the publicly available statistical units such as the Office of National Statistics' Super Output Areas (SOAs) and, moreover, the exact boundary of the exchange area is commercially sensitive. As a result, the operator joined the public geography of Output Areas with the private geography of exchange areas to create a 'public exchange area' (PXA) whose boundaries, since they were less sensitive, could be shared with us. The process resulted in SOA-linked polygons to which we could then append any of the standard socioeconomic data sets, including the NOMIS employment data and census population data.

Table 6.4 shows the overall distribution of PXAs at the scales that are most interesting to us. And Figure 6.9 gives a sense of how PXAs are distributed within the GSE region, while the inset highlights the concentration of telecommunications infrastructure within the London metropolitan area. The PXAs are shown here as points to address potential concerns with exchange boundaries being inadvertently revealed in areas where they are particularly fine-grained. As with the CLLI, the density of exchanges varies substantially with the density of people and businesses.

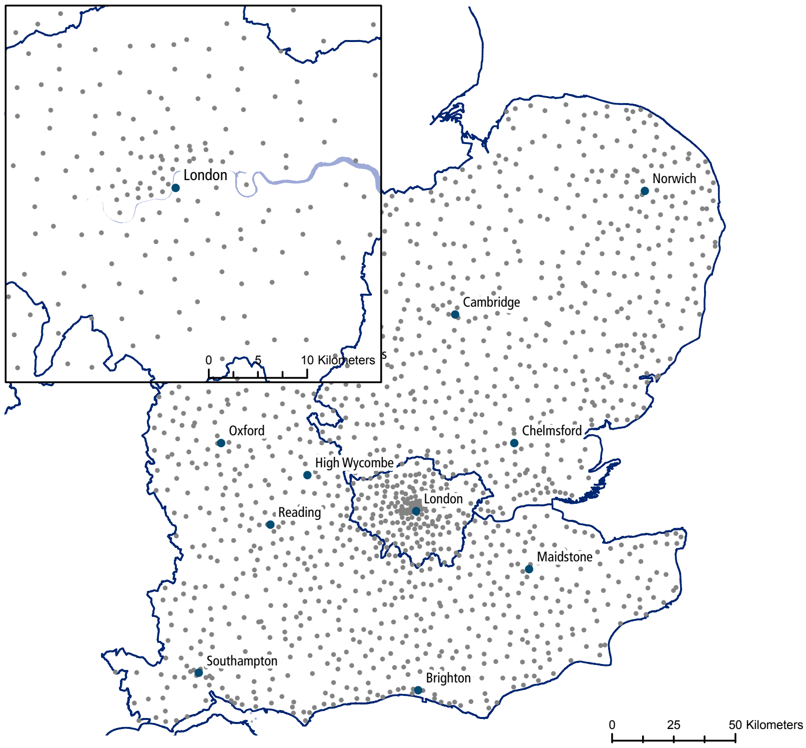


Figure 6.9: Mapping Exchanges in London and the Greater South East

Spatiotemporal Considerations

Although such massive data sets enable meaningful information to be extracted from tiny slivers of space and time, it is much more useful to look at the overall pattern of flows. Figure 6.10 shows an entire month's worth of calling activity on the British telecommunications company's data set, and one week's worth of activity on the wireline (*i.e.* landline) and mobile platforms for every CLLI in the American data set. What this shows very strongly is that there are daily and weekly cycles within the data, and that this holds true regardless of the data's origins or the type of telecoms data being studied[10]. Two features of particular note are: the obvious presence of a long weekend at the end of August in Britain, and the enormous surge in activity after the nightly 'watershed' for free mobile calling on the U.S. network.

[10] Obviously, in cultures where the work week is not synchronised with predominantly Christian traditions then we may see different patterns of usage.

The data from the major American telecommunications company also emphasises the extent to which different CLLIs and exchanges may carry very different levels of traffic: the red line marking the averages in Figure 6.10 falls a long way from the peaks observed in the data. Interestingly, the weekly cycle is particularly strong for dedicated lines,

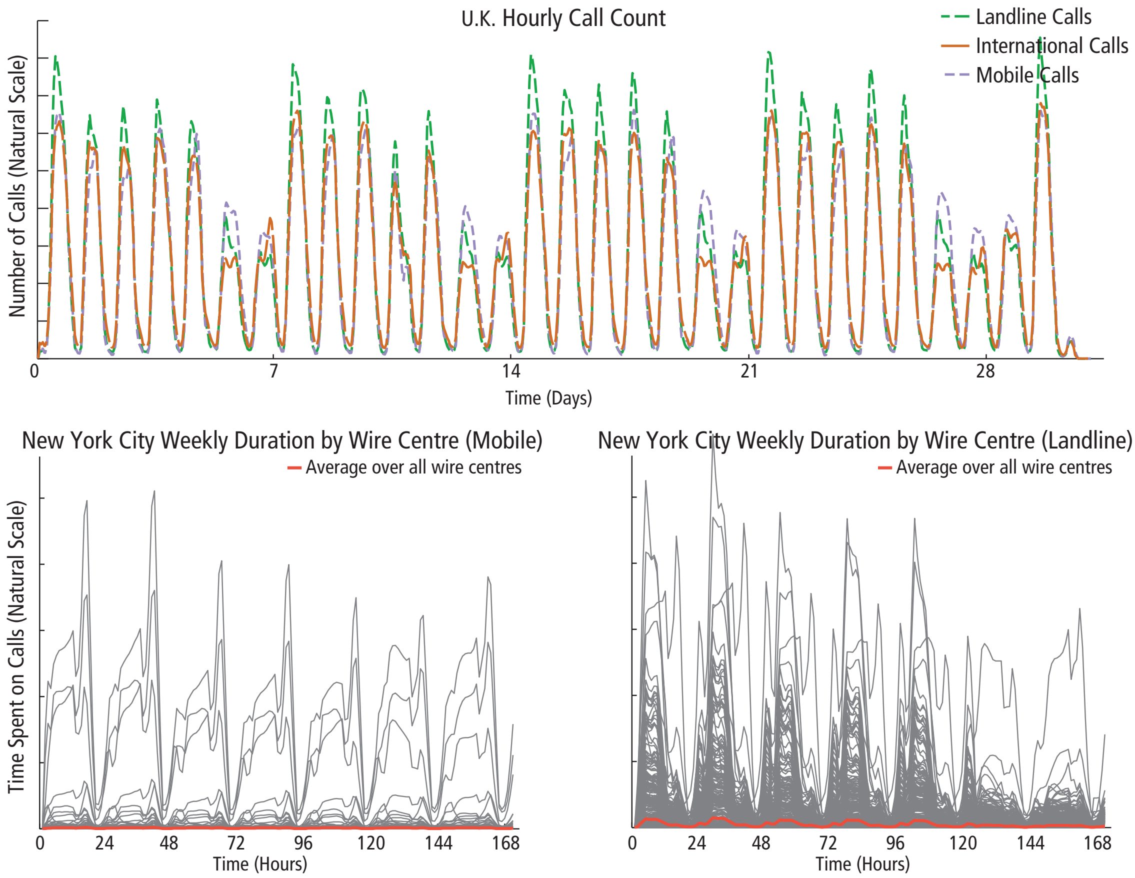


Figure 6.10: Global Patterns in New York and U.K. Data

reinforcing the idea that leased lines are dominated by businesses usage, while landlines show a similar, though less exaggerated, load pattern over the course of the week. However, the magnitude of the differences between the maximum and minimum loads on all of these platforms strongly implies that some kind of normalisation of the data is required: either log normalisation of the call data or, depending on the distributions, normalisation by population. Regardless, Figure 6.10 makes it clear that there are compelling reasons for focussing on the hour of day and the day of week as the critical analytical intervals.

Previous research using other telecoms data sources has also found that the diurnal and weekly cycles are the critical ones: the Fourier Transform shown in Figure 6.11 highlights the most prominent temporal cycles in WiFi activity using their magnitude: so higher peaks are more meaningful to the analysis of the data. In the case of the M.I.T. WiFi data, 24 hours (*i.e.* 1/0.04 hours) is by far the most prominent feature, followed by 1 week, 48 hours, 12 hours and 8 hours in declining importance. In every case, cycles lasting longer than one week were found to be of marginal importance to the observed data when compared to the diurnal cycle of waking up, heading to work, breaking for lunch, and then heading out or home in the evenings.

The weekly cycle is also particularly useful is in distinguishing between office and home locations since these show very different levels

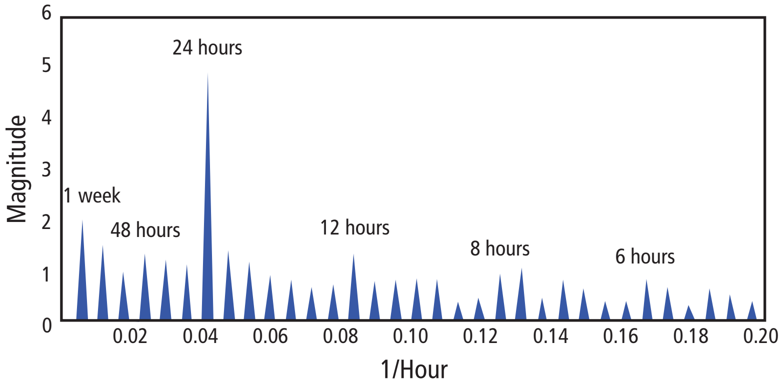


Figure 6.11: Fourier Transform of M.I.T. WiFi Data

of use over the weekend. By averaging together the four weeks of data in the data sets into a single representative week, we can also control for the random variation of day-to-day activity over the course of the month (including holidays and special events), reduce the overall size of the data set being analysed, and work with a timeframe that is particularly suited to picking up the differences between CLLIs and exchanges.

6.6 *Analysing the Data*

Over the past two years I have worked closely with M.I.T.'s Francesco Calabrese to extend the 'signature analysis' method first proposed by Ratti et al. (2006). Using data from a variety of providers and platforms in Rome and Boston we obtained early, but quite exciting, results and this work seeks to bring together the techniques developed in those publications (cf. Reades et al., 2007, 2009; Calabrese et al., 2010) with these extraordinarily rich data sets in order to more fully test the validity of the methods.

In this section we will first review the analysis of industrial concentration using the Location Quotient (LQ) and consider some methodological issues to do with the normalisation of irregularly-distributed data. Next, we will consider a Telecommunications Quotient (TQ) approach, modelled on the LQ methodology, to see if it has analytical benefits for rapid exploratory work. Finally, we will turn to the eigenplace analysis, which uses the output from an eigendecomposition process to feed a clustering algorithm that enables us to compare and categorise hundreds of very different signatures according to their underlying similarities.

Employment Data

To provide a frame of reference for the telecommunications data, we need to first count the number of workers and residents in each telecommunications CLLI or exchange. Most studies of cities, regions, and agglomerations measure industrial concentration using Florence's (1948) Location Quotient (LQ), and so this metric provides a useful benchmark against which to compare phone usage data. If we can identify a systematic relationship between some feature of the telecommunications data and one or more industries then we will have found the characteristic signature of that industry and provided a template against which to test other signatures for similar industrial activity.

The Location Quotient (LQ) is essentially a form of normalisation designed to cope with the fact that employment is rarely uniformly distributed. To calculate the LQ, we compare the concentration of a particular industry in an area-of-interest against the *expected* concentration of that industry given its regional average. So the basic LQ formula is:

$$(\text{Employment}_{iA}/\text{Employment}_{A})/(\text{Employment}_{iR}/\text{Employment}_{R})$$

where, i is an industrial sector, and A is an area-of-interest within a benchmark region R. So a LQ of 1 means that the share of employment for industry i in area A is equal to the regional average for that sector. A LQ above 1 means that an industry is over-represented in area A compared to the region R as a whole, and a LQ of less than 1 implies under-representation. The LQ is a multiplier measure, so a LQ of 10 means that an industry is ten times more concentrated in area A than it is in the region R overall.

SELECTING THE REGION: Although the LQ is fairly straightforward, it should be obvious that the denominator terms E_{iR} and E_R establish an implicit frame of reference with important implications for the resulting analysis. Depending on whether R is a metro area, a region, or a nation, derived LQs can change substantially. For instance, if we take i to be the financial and commercial banking sectors and use census tracts in New York City (NYC) as the relevant A, then switching from using New York State as the R to NYC causes the peak LQ to fall from more than 30—thirty times more concentrated than the state average!—to 'just' 16.

This issue was considered by Hall (1962, p.17), and he developed the 'Local Location Quotient' (LLQ) for the study of the industries of London. Quite simply, the LLQ is an explicit acknowledgement of the fact that there is usually a region of interest being explored in this sort of work, and that data from outside the region may be either less reliable, or less reliably comparable. This approach also keeps the focus firmly on *relative* differences in industrial concentration, rather than absolute ones, and this is relevant to our proposed analyses of the highly-specialised areas that make up London and the Greater South East of England (GSE)[11].

Because the data supplied by the U.K. network covers such a large area, it supports flexible and intensive investigation. So I will first perform a LQ analysis of the London metropolitan area to provide some useful, if partial, insight into the functioning of a 'world city'; however, this is only the first step since I will also perform a similar analysis using the much larger Greater South East of England (GSE) region. This larger region should contain the entirety of the London Mega-City Region (MCR[12]) hypothesised by Pain and Hall (2008) in POLYNET and other recent publications, but whose functioning has only been understood

[11] The American telecommunications company data only covers activity within New York City anyway, so it seems sensible to select the city as the benchmark R here as well—we can't see usage outside of the city, so we have no way of knowing how it might differ from usage within the city.

[12] The formal definition of the MCR is that it consists of "a series of anything between twenty and fifty cities and towns, physically separate but functionally networked, clustered around one or more larger central cities, and drawing economic strength from a new functional division of labour" (Hall, 2009, pp.806–807).

to-date in terms of commuting and labour markets. Consequently, this will be the first time that we have been able to explore the informational flows within something resembling a 'megalopolis'.

Selecting the Area: The nature of the exchange and the clli create a basic 'unit of analysis' below which we cannot conduct any viable research, making this the natural choice for the numerator (A) in the lq analysis. The size of each exchange, and the number of workers and residents that it contains, varies with the overall density of activity, so there is no set size for the area served by a switch. The process of normalisation involved in calculating the lq helps to control this potential source of comparability problems because large concentrations of employment tend to have both a large numerator and a large denominator.

Dividing by physical area would serve very little purpose here since the area of a pxa or clli is largely meaningless: at the very least we should be using the total floor area, but all this would accomplish would be to further emphasise the communication peaks at a small number of extremely active locations without in any way helping us to control for working or residential population. Furthermore, if we were to take this approach then we would also want to apply the same area-based normalisation to the telecoms usage data in order to generate mutually comparable data sets[13].

[13] In the event that it became necessary to control for area A's size then the lq for sector i could be recalculated using the following formula, which includes a measure of employment density:

$$\frac{\frac{(\text{Employment}_{iA}/\text{Employment}_{A})}{\text{Area}_{A}}}{\frac{(\text{Employment}_{iR}/\text{Employment}_{R})}{\text{Area}_{R}}}$$

Normalising by the area of A and R would tend to intensify the employment peaks in downtown areas since these have correspondingly smaller physical sizes.

Standardising the Location Quotient: Although we can calculate the level of concentration for a particular industry, there is, in fact, surprisingly little consensus on what constitutes a *significant* level of concentration (*i.e.* an agglomeration) for an industry (O'Donoghue and Gleave, 2004). Is it a lq of 2, which is twice as concentrated as the regional average, or a lq of 20, which is twenty times as concentrated? Many studies of industrial concentration use arbitrarily-selected thresholds for identifying agglomerations—these typically range from 1.25 to 3—but O'Donoghue and Gleave (2004) note that these values lack any statistical, or even rational, justification.

The issue is that the degree of concentration that is meaningful ultimately depends on the sample size and on the overall distribution of an industry: in the case of nyc's banking sector, the lq rises to more than 15 times the metropolitan average, but this grouping does not necessarily constitute a *statistically-significant* level of concentration because there are not many areas that contain *any* high finance. So whereas basic retail establishments tend to be fairly common and evenly distributed because everyone needs to shop for groceries, investment banking tends to be quite rare and quite unevenly distributed since only a few corporations or clients require their services. So in the former case, a lq greater than 1.5 could be an important clue that there is a site of particular interest to retailers that is worth investigating in more depth, while for finance the tiny sample size and uneven distribution may not offer any insight at all into whether these groupings are deliberate or the product of mere chance.

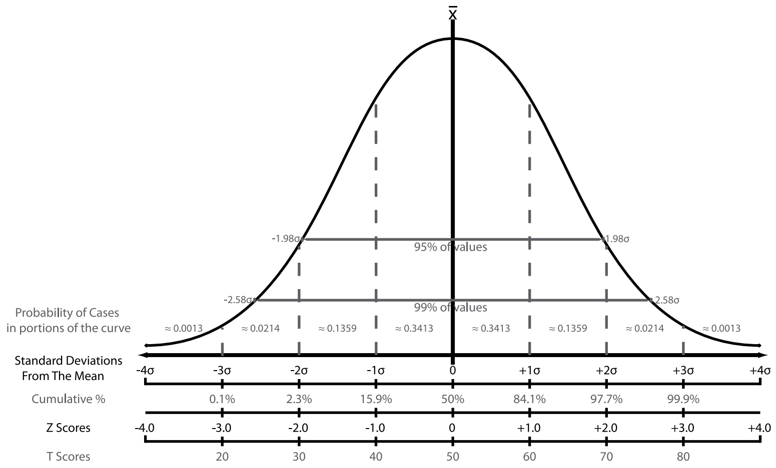


Figure 6.12: The Normal Distribution (Wikipedia, 2007; reproduced with permission)

So to determine if a particular LQ value has any statistical significance, we therefore need to know the overall distribution of LQs. Following O'Donoghue and Gleave (2004, p.422), we can calculate a Standardised Location Quotient (SLQ[14]) and test for normality. If the overall distribution is normal, then we can look to the standard deviation as a guide to whether there is significant over- or under-representation of an industry in a particular area. However, as Figure 6.12 shows, standard deviations do not *quite* map cleanly on to the confidence levels normally used in statistics, and remember too that a 5% confidence level implies a 2.5% probability of finding a value below the lower boundary and a 2.5% probability of finding a value above the upper one.

The two most commonly used confidence levels are 95% (equivalent to the range between $\approxeq -1.96$ and $\approxeq +1.96$ standard deviations) and 99% (equivalent to $\approxeq \pm 2.58$ standard deviations[15]). But before we can work with these standard values, we need to confirm that the distribution is actually—or at least plausibly—normal. O'Donoghue and Gleave suggest checking the raw LQs for normality using the 1-Sample Kolmogorov-Smirnov Test (K-S Test) [16]. If the raw LQs are not normally distributed, then they suggest taking the log of each LQ and testing the resulting distribution for log-normality using the Monte Carlo method within the 1-Sample K-S Test[17].

Additional research, however, suggested that the Lilliefors test would be a more appropriate solution since this test uses the mean and variance of the observed data to create a normal distribution that can be tested against the empirical one[18]. Finally, although it *is* possible to adjust the LQ to control for the predominance of large firms (O'Donoghue and Gleave, 2004, p.423), however the NOMIS business data from the U.K. and the standard business data from the U.S. do not support this process.

Telecommunications Quotient

In much the same way that we can measure the relative concentration of employment, we can also calculate a concentration/specialisation metric

[14] More accurately, if were to keep with the method set out Hall (1962) then these would be Standardised Local Location Quotients (SLLQs), but this is becoming quite a weighty acronym and so I have used SLQ as shorthand for this approach throughout the text.

[15] Often, instead of speaking of standard deviations, analysts speak of z-values or z-scores, which are functionally equivalent.

[16] Implemented in SPSS under: Analyze → Non-Parametric Values → 1 Sample K-S Test

[17] Implemented in the SPSS application under: Analyze → Non-Parametric Values → 1 Sample K-S Test → Exact Tests

[18] Implemented in MATLAB as `lillietest(x,alpha,dist,mctol)`, where x is the input vector, $alpha$ is the significance level, $dist$ is the type of distribution for which to test (normal, exponential, or extreme value), and $mctol$ forces MATLAB to calculate a Monte Carlo approximation for p instead of using a lookup table.

for telecommunications. Using what I will call the 'Telecommunications Quotient' (TQ), we can compare the share of traffic to/from a point of interest anywhere in the world for which a given area A is responsible against the regional average (*i. e.* R). The basic calculation is therefore as follows:

$$(\text{Traffic}_{pA}/\text{Traffic}_{A})/(\text{Traffic}_{pR}/\text{Traffic}_{R})$$

where, p is a place of interest (*e.g.* Los Angeles or Japan), A is an area-of-interest (*i. e.* CLLI or PXA) within region R, and R the benchmark region. This calculation would work equally well with either the number of calls, or their duration.

I anticipate that we will need to include both domestic and international traffic in this calculation because this will contextualise the TQ within the overall level of activity. For instance, an area with little international traffic could demonstrate large shifts in the TQ with only small shifts in the relative intensity of calling to a particular country. Using this approach, it transpires that many suburban and rural areas place or receive so few international calls—and, conversely, that urban areas place so many—that the *majority* of PXAs have TQs of less than one. Consequently, the idea that unity represents an overall regional average is misleading in this case, and we find that few of the TQs calculated for British PXAs have a normal *or* log-normal distribution. Accordingly, the concept of a standardised TQ (STQ) is of rather limited analytical value here.

Nonetheless, this approach has several advantages: first, much like the LQ, it controls for widely varying levels of telecoms usage; second, it yields a singular metric which could be compared with the figures calculated for employment; and third, its simplicity means that we can test a variety of approaches quickly and easily. Significantly, this is rather a different approach to the data from what was found in the seminal early work by Graham and Marvin (1996) and, to a lesser extent, by Sassen (2002) which tended to focus on raw numbers at the urban scale. Limitations in the data to which these and other researchers had access made more subtle comparisons difficult, or even impossible, but normalisation is crucial if we are not to simply find that cities are global telecommunications hubs.

Eigenplace Analysis

OVERVIEW: While the concept of TQs provides one approach to the telecoms data, we have not yet taken advantage of its temporal aspects. To do so, we will need turn to computational methods that draw on techniques used in signal analysis and remote sensing. Eigendecomposition operates in a manner similar to factor analysis, and this, in the form of a 'matrix analysis', has notably been previously used by Goddard in a 'regionalisation' analysis of taxi flows within London (1970; and see also Goddard, 1973, pp.25–29). The process enables us to convert a large number of unique, noisy 'signatures' into a much smaller number of place-specific coefficients that are suitable for both manual and automated categorisation. In combination, these eigenvectors and eigenvalues enable us to extract and categorise the underlying, recurrent features of the observed data from each area, and to generate a telecommunications-based classification of space.

THEORY: We can think of each CLLI or exchange as a kind of probe that returns a set of observations—that there were x calls to Canada and y minutes to Indonesia, for instance—about its environment. The challenge is that each area will show a different level of overall usage that reflects both the density and the mix of local activity. How, for instance, do we recognise that there is a similar—but not identical—pattern of activity in the City of London (where the activity would be driven by dozens of financial institutions) and in Cambridge (where the activity might be driven by a single large financial firm embedded amongst several other sectors)? We need a way to simultaneously manage two effects: a scale-effect that encompasses the concentration of activity, and a mix-effect that captures the way that a blend of causes can contribute to the observed signal.

Eigendecomposition enables us to address both of these issues: the process yields an ordered set of linearly independent[19] vectors (termed eigenvectors) and linked coefficients (termed eigenvalues). Because the eigenvectors are independent, each one accounts for a different aspect of the observed signal, enabling us to grapple with the mix-effect; because each vector has an associated coefficient, we can also address the scale-effect of concentration. Furthermore, by performing the eigendecomposition for the *entire* data set at once, we obtain a single set of eigenvectors that are the same for all locations; only the eigenvalues vary from place to place.

[19] Linear independence is important since it means that the derived vectors are all orthogonal and, much like the coordinates obtained from multidimensional scaling (MDS), 'may be treated as separate dependent variables' (Barnett and Choi, 1995, p.254).

However, this process is easier described than done: for each PXA we have 7 days × 24 hours observations for *each* dimension used in the analysis. So even if we choose just three dimensions—minutes to Canada, calls to Continental Europe, and minutes to Brazil, for instance—as the basis for classifying an exchange, then we are looking at a minimum of 700,000 data points for the GSE (7 days × 24 hours × 3 dimensions × 1,400 PXAs), and more than 1.8 *million* observations for all of Britain. In fact, we have many, many more dimensions than this from which to choose and so the 'problem space' is even larger than this.

KNOWLEDGE DISCOVERY IN DATABASES: Moreover, we cannot expect a single usage dimension (or even several different dimensions) to yield a categorisation that 'works' for all sectors and all activities because many uses overlap in both space and time: an area might easily be both residential *and* financial, with both 'activities' happening throughout the day and night. So instead of performing a single analysis and deriving one set of clusters, we will approach the analysis iteratively and may well find that the output of one filtering or clustering process becomes the input to another, subsidiary one.

Fortunately, we have a relevant analytical model in interactive Knowledge Discovery in Databases (often abbreviated to KDDi). This approach has already been applied to large spatial data sets: Rinzivillo et al. (2008) employ an iterative clustering approach to analyse trip data from Milan in order to understand the relationship between journey origins and destinations. Their approach successfully balances both the computational impossibility of analysing all dimensions simultaneously with the analytical risk that 300 clusters proves to be the 'mathematically correct' result but has no value as an interpretative tool.

As well, an entirely automated analysis might select data dimensions that have useful analytical characteristics but no underlying *meaning*. To try to put this in more concrete terms: if were to feed into the data mining process aggregate calling to and from two countries of very different sizes—France and the Turks and Caicos Islands, for instance—then the results might prove rather misleading because there may be just a few exchanges or CLLIs with high-levels of calling to the Turks and Caicos and a large number with very little calling. Unfortunately, this distribution might seem like a good 'spread' to an algorithm while, in contrast, the French calling data seems less relevant because it has less variation. We can control for this issue (the significance of very small numbers and very large variations) by taking the log of the raw data, but to a human it is still obvious that small variations in the French data will generally be more 'meaningful' than large variations in the Turks and Caicos data, and that small-samples should be handled with care.

IMPLEMENTATION: The number of calls to or from a given place (*i.e.* an individual exchange or CLLI) can be represented as a 1×168 vector; that is, we have data for 1 CLLI (1 row) with 7 days × 24 hours of observation (168 columns). We can then vertically stack the descriptive vector for each CLLI to create a single $m \times 168$ matrix, where m is the number of exchanges in the data set (see Table 6.5 for an abbreviated example). This is now a covariance matrix suitable for eigendecomposition (Joliffe, 2002).

The process is illustrated in schematic form in Figure 6.13, but note how two quite different signals can be reconstructed from just two eigenvectors: exchange #1 is composed entirely of the 1st eigenvector (with magnitude 1.5), while exchange #2 is composed of a mixture of the 1st and 2nd eigenvectors, both with magnitude 1.

Exchange	Day 1/Hour 1	Day 1/Hour 2	···	Day 7/Hour 23
NYC——	397.65666	257.56666	···	1359.03750
NYC——	431.01333	232.11000	···	584.67500
⋮	⋮	⋮	···	⋮
NYC——	1285.56331	826.78334	···	2127.89166
NYC——	5899.10332	3897.76335	···	792.09167

Table 6.5: Sample Input Data Matrix for Duration of Calls

In more technical terms, after eigendecomposition each CLLI or exchange's original signal can be expressed as a sum of the global eigenvectors V_i, for $i = 1, \ldots, n$, each modified by a set of PXA-specific coefficients C_i, for $i = 1, \ldots, n$. So if S_i is the signature observed at a randomly selected exchange i, then after eigendecomposition its original signal can now be described by the equation:

$$S_i = C_{i1}.\underline{V}_1 + C_{i2}.\underline{V}_2 + \ldots + C_{in}.\underline{V}_n$$

where C is the coefficient or eigenvalue and V the eigenvector. Furthermore, these are ranked such that $C_{i1} * V_1$ is the most important principal component in the original signal S_i.

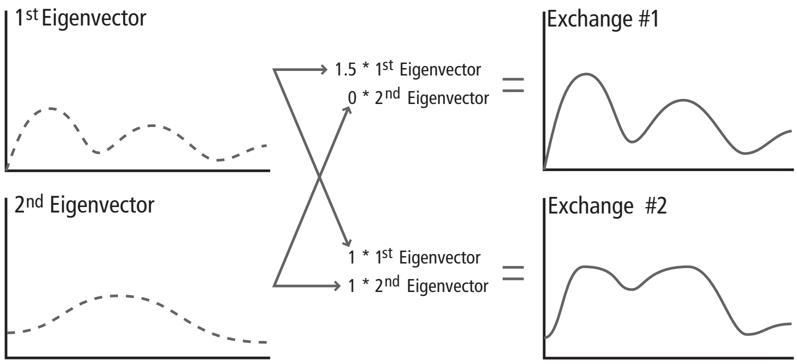


Figure 6.13: Illustration of the Eigendecomposition Process

However, since we have performed the eigendecomposition on *all* exchanges simultaneously, the signature of a second exchange S_j can also be described with the *same* set of vectors V_1 through V_n, but with differing coefficients C_{j1} through C_{jn} (*i.e.* $S_j = C_{j1}.\underline{V}_1 + C_{j2}.\underline{V}_2 + \ldots + C_{jn}.\underline{V}_n$). So now we have compressed thousands of unique, noisy, complex, time- and space-varying signals into just one set of vectors shared by all CLLIs, and we can now distinguish between them using *only* the eigenvalues since the vectors are the same for all CLLIs. In effect, if we want to compare and categorise the exchanges, then we have only to examine the eigenvalues and, as we will see in the following section, this a much simpler process computationally and analytically.

Figure 6.14 draws on mobile data from Rome used in earlier research (see Reades et al., 2007) to illustrate the application of eigendecomposition to a simplified version of a real data set. In the top half of Figure 6.14 are the raw data (measured in Erlang[20]) fed into the eigendecomposition process, in the bottom half are the derived eigenvalues for each day of the week. At this point, the eigenvectors are no longer strictly relevant to the comparison of the signals at each site because the vectors are the *same* for all three locations.

The magnitude of the eigenvalue is related to the importance of the eigenvector in the original signal, so in this case the first eigenvalue (of magnitude 2 in nearly every location for most of the week) is connected to the most prominent common feature of the data set: the daily, double-peaked cycle of phone usage. We can also infer this relationship without needing to refer to the eigenvector because the first eigenvalue is positive for weekdays and only changes on weekends when lower overall usage is visible in the plots. The second eigenvalue can be seen

[20] The Erlang is a unit of telecommunications traffic usage. Roughly, the Erlang is the average call 'density' over some period of time, and so one Erlang is the *equivalent* of one call lasting the duration of the time period. Normally, the time unit is an hour, meaning that 1 Erlang is 3,600 seconds of phone usage during in one hour; however, note that this value could be achieved in many different ways: it could mean one call than lasted 3,600 seconds, or 360 calls that each lasted just 10 seconds. See SearchNetworking.com (2000) for more information.

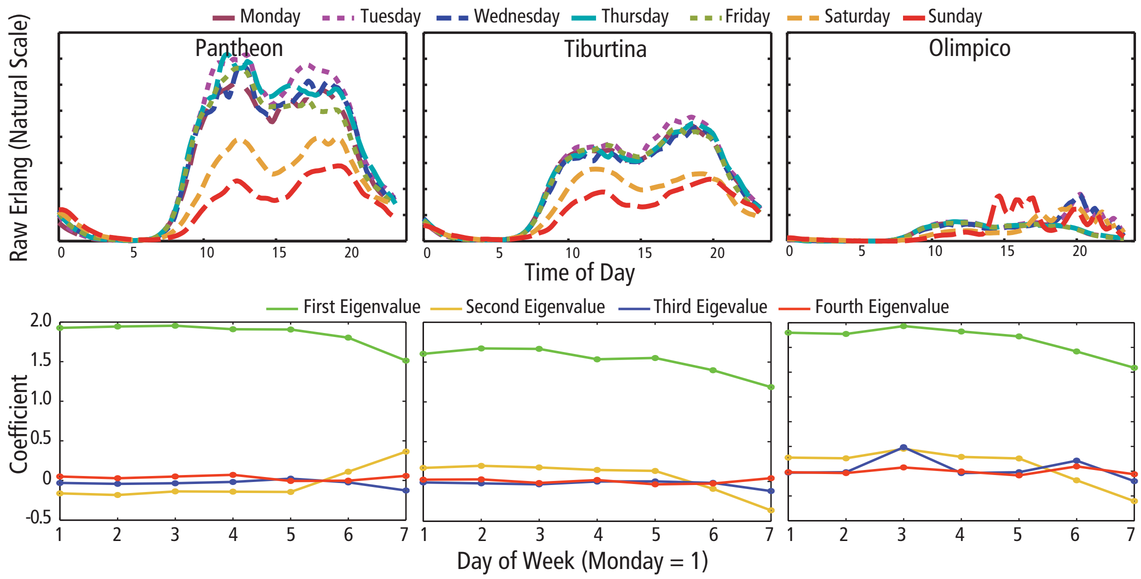


Figure 6.14: From Signals to Coefficients (Reades et al., 2009)

to capture a different aspect of how usage changes on weekends because its value also changes quite significantly on Saturday and Sunday after remaining steady throughout the week. The third eigenvalue appears to record an evening surge in activity since it rises at Olimpico on Wednesdays and Saturdays when sports fixtures occur.

Feature Selection

Although eigenvalues offer some basic insight into patterns of activity, the most important reason for calculating them is that they are simple scalars and so are also amenable to standard types of dimensional analysis. In effect, we can treat each eigenvalue as a dimension, and will eventually be able to group each exchange by its degree of similarity to all of the others across the different values. There are many ways to group observations (or, in this case, eigenvalues) into categories but the principal issue that we need to consider is whether and to what extent to guide the categorisation process. Since telecommunications data and its use in this context are largely new to built environment research, I felt that it was best to employ an unsupervised approach in which no *a priori* assumptions are used to structure the analysis.

In real-world data sets, eigendecomposition produces dozens, or even hundreds of eigenvalue/eigenvector pairs. The issue that this introduces is that we can't know *which* eigenvalues are the most significant for our analysis, we only know which are the most important for reconstructing the original data. Fortunately, this problem is well-understood as one of 'feature selection' in which we examine the distribution of eigenvalues along each dimension and discard ones that add little to our understanding of the data so as to retain only a smaller, representative set of eigenvalues from the data.

In many ways, the feature selection process employed here is similar to the clustering process that will be discussed in Section 6.6 (page

245), in that we are grouping values according to their degree of similarity. For instance, imagine that we find that the 1st, 5th, and 7th eigenvalues have similar distributions across all of the locations captured data set, then for the purposes of examining calling activity across the region R we only need one of these three eigenvalue sets and can safely ignore the other two. This step would radically simplify the subsequent phases of the analysis, and is exactly what we accomplish using a MATLAB-based implementation of an algorithm for unsupervised feature selection.

The idea here is to partition (*i. e.* group) the features into a number of homogeneous subsets, and then select a representative feature from within each group. The approach developed by Mitra et al. (2002) manages this by leveraging the concept of 'maximal information compression' (2002, pp.303–304); it takes a data matrix (x, y) and calculates the smallest eigenvalue—which it terms the *maximal information compression index* (λ_2)—such that:

$$\begin{aligned} 2\lambda_2(x,y) &= \mathrm{var}(x) + \mathrm{var}(y) \\ &\quad - \sqrt{(\mathrm{var}(x) + \mathrm{var}(y))^2 - 4\mathrm{var}(x)\mathrm{var}(y)(1 - \rho(x,y)^2)} \end{aligned}$$

where ρ is given by the covariance matrix over the square root of the variance between the two variables (*i. e.* $\rho(x,y) = \frac{cov(x,y)}{\sqrt{var(x)var(y)}}$).

The process can be summarised as follows:

- we compute the k nearest (most similar) features of each subset (feature similarity is defined by the maximal information compression index $\lambda_2(x,y)$);
- the feature having the most compact subset is selected and its k neighbouring features are discarded.
- the process is repeated for the remaining features until all of them are either selected or discarded.

Implicitly, the value of k is user-specified such that we retain only the 5, 10, or 50 most relevant features from the 20, 100 or 500 original features extracted from the data set via eigendecomposition. Applying this algorithm to a small data set of wireless and landline international calling to and from New York City, and specifying the selection of 20 features, results in the features listed in Table 6.6 being selected for the subsequent clustering process.

Data Source	# of Features	Features Selected
Outbound Wireline	5 (25% of total)	Eigenvalue 1, Eigenvalue 2, Eigenvalue 5, Eigenvalue 6, Eigenvalue 10
Inbound Wireline	6 (30% of total)	Eigenvalue 1, Eigenvalue 3, Eigenvalue 4, Eigenvalue 5, Fourier Transform 8, Fourier Transform 33
Outbound Wireless	2 (10% of total)	Eigenvalue 4, Fourier Transform 1
Inbound Wireless	7 (35% of total)	Eigenvalue 1, Eigenvalue 3, Eigenvalue 4, Eigenvalue 5, Eigenvalue 8, Eigenvalue 9, Fourier Transform 8

Table 6.6: Selected Features for Calling to and from New York City

It is worth noting that in this particular example both the data selected and the feature selection algorithm have functioned quite well for our purposes: the majority of the features listed in Table 6.6 are higher-ranked ones—*i. e.* the lower-numbered eigenvalues and Fourier Transform frequencies—meaning that there are only a few that are likely to represent quite minor behavioural patterns or cycles (*e. g.* Fourier Transform 33 from Inbound Wireline), and no one data set dominates the final selection. What this indicates is that the input data varies in significant ways *and* that the algorithm is not being 'misled' by the noise that characterises the lesser-ranked features.

Cluster Analysis

Since we want to allow urban structure to emerge from the data, rather than imposing our preconceptions upon what it should show, we want a 'bottom-up' classification and the k-Means method is an appropriate approach. The method partitions (*i. e.* groups into parts) a set of observations $(x_1, x_2, x_3, \ldots, x_n)$ into k sets (where $k < n$) such that each observation is as much like the other members of its own group, and unlike members of any other group, as possible. Similarity is measured by the distance between each observation x_j and the mean vector μ_i for the set S_i of which it is a member. In other words, we calculate the centroid for a group S_i using all of its members, and can then measure the distance of every x from that centroid.

In practice, there are a number of ways to measure the distance between a vector x_j and the mean vector μ_i. However, the simplest approach is to use the multi-dimensional Euclidean distance, and then sum this value for all members of the cluster using the following formula (Wikipedia, 2005b):

$$\underset{S}{\arg\min} \sum_{i=1}^{k} \sum_{x_j \in S_i} \|x_j - \mu_i\|^2$$

So we are trying to find which cluster centroids (*i. e.* mean vectors μ_i) would produce the smallest possible within-cluster sum of squares distance for all n observations. In (more) plain English, we start off not knowing which observations belong in which groups, so we take k random starting points, assign every observation to the closest starting point, and then calculate the mean value of each cluster. If, after calculating the mean vector μ_i we find that some observations are actually closer to a different group's mean vector μ_j, then we reassign it from one cluster to another and recalculate the mean vectors once more. Over many iterations, we gradually converge on a stable distribution in which we cannot reassign any observations from one group to another without increasing the size of one or more of the mean vectors. Consequently, the best clustering is the one for which the sum of the distances within each group is at a minimum (*i. e.* $\arg\min$).

However, we need to repeat the *entire* process multiple times because it is nearly impossible to calculate an optimal clustering in just one go, even for a data set of very modest size. As a result, computer scientists have adopted an iterative approach to clustering since, over many, many iterations, the centroids gradually converge on a stable distribution and no further reassignments take place. With only a single pass at the data the results would be highly sensitive to the initial conditions (*i. e.* the coordinates selected for the first centroids), so by repeating the *entire* clustering process multiple times with different random seeds each time it becomes possible to derive a stable set of clusters such that each x is assigned to the best S in a globally optimal way.

The one major drawback of the k-Means approach is that the value of k is a user-specified input and is not derived from the data itself. In other words, we decide how many clusters there are in the data, and while we may *think* that there are four groups, perhaps there are actually five. Or ten. Or just two. Consequently, we need a way to evaluate which value of k provides the best fit for the data. Fortunately, the appropriateness of a clustering solution can be gauged both mathematically and visually using the silhouette values (Rousseuw, 1987). An s-value close to +1 means that the element is appropriately clustered, while an s-value close to -1 suggests the element is not a good fit for its cluster. So the silhouette plot simply shows the s-value for each and every observation, and the average silhouette value measures how appropriately the data has been clustered overall.

Figure 6.15A shows the s-plot for a clustering of the eigenvalues derived from WiFi hotspots on M.I.T.'s campus. So in this figure, the data making up Clusters #1, #2, #3, and 5 appear to be well-grouped while Cluster #4 shows substantial internal variation, suggesting that it is rather more weakly clustered. The s-value calculation was performed using the following formulation in MATLAB:

$$S(i) = \frac{(\min(b(i,:), 2))}{\max(a(i), \min(b(i,:), 2))}$$

where $a(i)$ is the average distance from the i^{th} point to all other points in the cluster, and $b(i, k)$ is the average distance from the i^{th} point to all points in another cluster k.

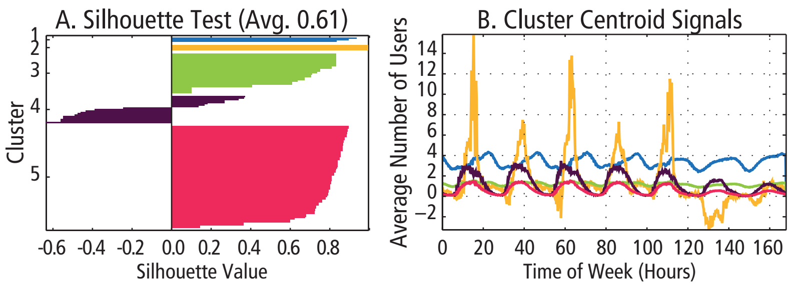


Figure 6.15: Silhouette Plot for WiFi Hotspot Eigenvalues (Calabrese et al., 2010)

We can mathematically compare the silhouette plots obtained for each k using the total area in the right half of the s-plot (*i. e.* $s > 1$) in order to determine the optimal value of k. Since the clusering process is run iteratively, what it actually yields is a probability density function (PDF) that is calculated for each value of k from multiple passes across the data. At this point, interactive collaboration between humans and computers becomes invaluable, because although two clusters may be the mathematically optimal solution—it picks up on a fairly basic distinction between high- and low-volume PXAs—it also seldom yields much in the way of new insight. Experimentation during the analysis phase suggests that the range $3 \leq k \leq 6$ yields the best balance between mathematical optimality and human interpretability: less than three and the difference is so basic as to be obvious, more than six and the clusters cease to have any kind of meaning or abstraction value (*i. e.* you tend towards a situation where every exchange is in its own cluster and so no generalisation is possible).

We can also use each cluster's mean vector μ_i to generate an average signal for the cluster. Figure 6.15B shows the *average* signal for each of the clusters obtained from the k-Means clustering whose results are shown in Figure 6.15A. This demonstrates how the process has captured distinct behaviours in each cluster: we can infer that Cluster #1 shows the regular weekly usage of undergraduate dormitories because it remains high over weekends when those are the only fully-occupied buildings, while Cluster #2 shows the sudden, massive surges in usage within auditoria whenever a big lecture takes place.

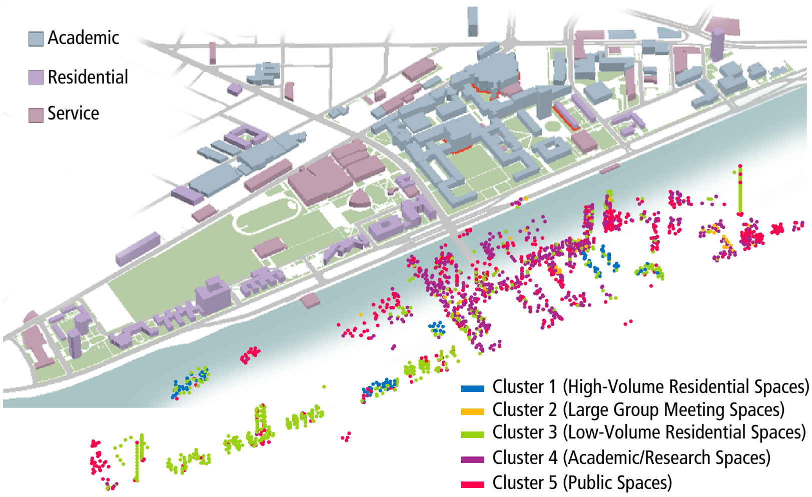


Figure 6.16: Eigenplace Analysis Results for M.I.T. Campus (Calabrese et al., 2010)

Finally, we can take the results from the k-Means analysis and project the clusters back on to the original geography from which the observations were drawn. Figure 6.16 shows the results of an analysis undertaken on M.I.T.'s campus using data collected from more than 3,000 WiFi hotspots. Working from the silhouette analysis shown above in Figure 6.15, we were able to show that from the standpoint of network *usage* M.I.T.'s campus had five distinct types of activity, and not the three land uses determined by the university's administration. The university campus is a fairly controlled and defined space, but if we can extend this analysis to the urban, regional, and even national scales, then this technique could change the way that we approach the collection of data—the low latency of telecommunications data (as little as 24 hours after collection) could, for instance, be used to identify areas where the census appears to be significantly out-of-date, enabling governments to prioritise them for sampling over those where there is little evidence of change.

Software Implementation

The application employed in this analysis was jointly-developed with Francesco Calabrese of the SENSEable Lab at M.I.T.[21], and the full process is illustrated in Appendix C: Eigenplace Analysis (see page 419). However, the basic sequence is as follows:

[21] In fact, credit for the implementation should go *principally* to Francesco Calabrese and Amedeo Buonanno of M.I.T.; I have focussed on data aggregation and management, extensions to the basic application, and aspects of usability and dimensional selection.

- Select call data for one or more continents, regions, countries, or exchanges/CLLIs of interest—there is one file for each geography (*e.g.* a continent or country of interest), and one row per file for each CLLI or exchange such that each row contains 7 × 24 columns of data;
- Calculate the principal components of the data (specifically, the eigenvalues and Fourier frequencies) for each input file;
- Calculate the 'spread' of the data across each of the derived features and retain only a representative subset of the full feature set so as to improve the clustering results (see Feature Selection below);
- Repeatedly cluster the remaining features for all locations using different values of k (*i.e.* different numbers of clusters) in order to generate a probability distribution function that enables us to identify the most meaningful number of clusters to use for a mapping;
- Select a value for k and map the clusters to see if significant relationships emerge.

Summary

Calabrese and I have termed the results of the eigendecomposition, feature selection, and clustering process an 'eigenplace' (2009; 2010) since it uses the principal components derived via eigendecomposition from an area's telecommunications usage to create a usage-based description of place. The analytical benefit of eigenplaces is that they are quantitatively comparable to any other places described with the same set of characteristic vectors. Since the coefficients are simple scalars, we can cluster areas based solely on the similarities and differences between the coefficients and then examine how these groups are distributed across space, using them to illuminate structural differences in telecommunications usage. By comparing eigenplaces with socioeconomic measures such as the LQ we can see if different industries and activities leave characteristic traces in the 'space of flows'.

6.7 *Conclusions: Analysing Telecommunications Data*

This chapter has sought to show how telecommunications data can be—and, in fact, already is—applied to the study of human society and of our urban systems. Thanks to the generous involvement of two major networks in this research, data has been collected on an unprecedented scale and with unparalleled detail—together, the data sets represent the combined calling patterns of more than 70 million people—firmly positioning this work within the evolving field of computational social science research. What I have sought to make clear, however, is that CSS does not exist in a vacuum and that, as such, it is simply one axis along which research into these systems can advance: this data offers critical insight into behaviour but can only try to explain motivation indirectly. In short, such work demonstrates the ongoing value of "integration between qualitative and quantitative methods in similar spatial studies" (Pain and Hall, 2008, p.1074).

The theoretical distinction between the LaGrangian and Eulerian analyses also points to the continued importance of attacking new types of data and new research challenges from several directions at once. To date, the majority of telecommunications network analysis has come exclusively from the LaGrangian perspective, but through the use of the eigenplaces analysis I hope to shift some of this focus on to the Eulerian approach. If this effort is successful, then this would put the comparative and relational components of inter- and intra-urban telecommunications flows on an equal footing in research.

The eigenplace analysis also has significant advantages from a privacy standpoint because it does not rely on the sharing of any individually-identifiable (not even pseudonymous) interactions. One possibility is that data in this form might constitute an interesting half-way point on a journey from the existing situation of highly circumscribed and piecemeal access by privileged teams to a future where more fine-grained data—stripped of its identifiers to a societally-acceptable level—is more freely shared between corporations and academe. Data in this form would be more readily intelligible to both Institutional Review Boards and regulators (cf. Lazer et al., 2009, p.722), and might therefore stimulate innovation in products and services—see, for instance, Sense Networks' CitySense application (2008)—that would generate incremental revenue for operators as well as new means of understanding urban environments for social science researchers.

7
Analysis

7.1 Introduction

In this chapter we will explore telecommunications activity at the urban and regional scales with a view to determining whether aggregate usage across space and over time reflects underlying activity, or mixes of activity, in a systematic way. Our objective is to see whether telecoms activity can be used to prove or disprove the theory of informational flows elaborated across the previous six chapters, and we will be examining four different scales: urban, regional, national, and international. We can, for instance, examine where calls originating in London 'go to', or where calls terminating in that city 'come from'. We can also look at the timings of these calls throughout the day or week. Ultimately, we will consider if the intersection of these two dimensions can be used to extract greater detail from this abundance of interaction data.

So what should we expect? Based on the summary and hypotheses set out in the Methodology (see page 207), we expect the distribution of firms to break down along three axes. So firms employed in predominantly Analytical activity such as R&D, and to a lesser extent ICT, should show more in the way of long-distance flows than, say, the 'creatives' in Soho because their outputs are more readily codifiable; they should also show higher levels of dispersion because their reliance on F2F interaction is thought to be lower, although they may obviously benefit from agglomeration effects in the sourcing of resources.

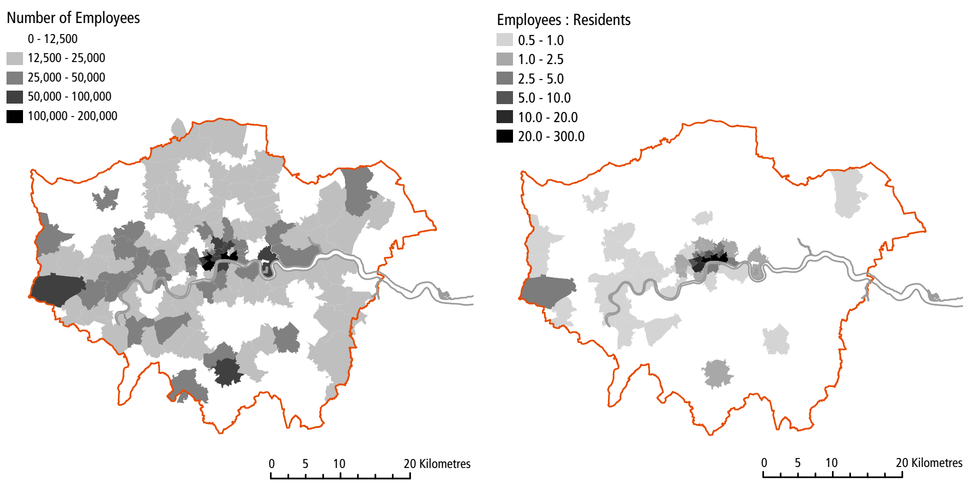
In contrast, Symbolically-oriented firms involved in cultural and artistic outputs should demonstrate high levels of clustering in core cities because it is there that multilateral flows operate most cheaply and effectively. Finally, Synthetically-oriented firms with a reliance on bilateral interaction may be expected to show a mix of scales and flows—they should be concentrated, but not necessarily in the Central Business District (CBD). Underlying this sectoral dynamic, we should also expect to see increasing levels of internationalisation across *all* sectors as we move towards core activity areas, and we should expect to see greater use of telecommunications as firms seek to coordinate increasingly complex activities.

7.2 *Spatial Data Overview*

In order to answer the first half of the hypotheses—those to do with industrial location—we will examine sectoral spatial structure in Britain at two scales: London, and the Greater South East of England. The latter, often referred to by the acronym GSE, is composed of three large Government Office Regions: London (1,600km^2), the South East (19,000km^2), and the East of England (19,600km^2). Together, these regions contain one-third of Britain's population (21,010,194 using the mid-2005 estimates), and nearly 10,000,000 workers across an enormous range of industries. Increasingly, the GSE is seen as the true economic 'heart' of Britain since employment growth within these three regions has consistently out-paced the rest of the U.K. (see Figure 5.5 on page 201). Moreover, unlike much of the North, jobs growth here has been driven primarily by private sector instead of public sector hiring. The intention is that this overview will improve our interpretation of the results contained in the subsequent sections.

Employment Distribution

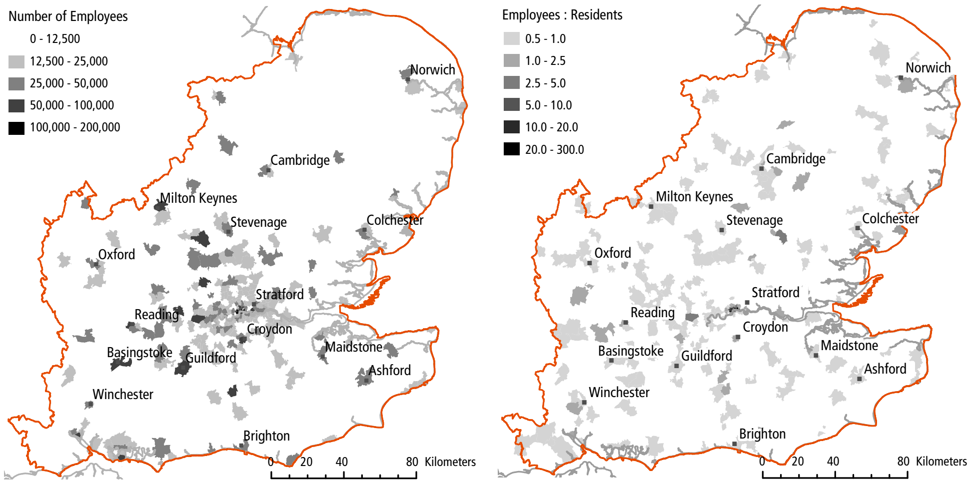
London's general socioeconomic geography is probably well-known to most readers; however, comparing absolute and relative levels of employment—relative to the number of residents in the same area, that is—yields a more nuanced picture since we can expect large imbalances to highlight in- and out-commuting areas. Figure 7.1a emphasises the sheer scale of London's labour market, with 3 public exchange areas (PXAs) containing more than 100,000 employees, 9 PXAs with more than 50,000 employees, and a staggering 30-odd PXAs with more than 25,000 staff. Although employment is distributed widely across London, there is a pronounced western bias for the largest centres. This dynamic is reinforced in Figure 7.1b, which shows the ratio of employees to residents: although it is disproportionately high in the traditional CBD of the City and West End, there is a clear 'wedge' shape to the West.



(a) Absolute Employment Levels (b) Ratio of Employment To Population Levels

Figure 7.1: Employment by PXA in London

Absolute employment in the GSE is also widely distributed (see Figure 7.2a), although the East of England contains rather fewer major centres of employment. And while the London metro area is still the most prominent at this scale, important concentrations of workers can now also be seen at Milton Keynes, Oxford, Reading, Basingstoke, Cambridge, Guildford, and Maidstone. Figure 7.2a also highlights the importance of airports: Heathrow, Gatwick, and Luton are all prominent employment centres in absolute terms. Switching to the ratio of employees to population (see Figure 7.2b) modifies this picture slightly, although the East is still notable for the absence of major centres. In particular, the widespread density of employment to the West and South of Central London seems likely to be of interest, but we can also see a smaller number of seemingly important sites towards Cambridge.



(a) Absolute Employment Levels

(b) Ratio of Employment to Population Levels

Figure 7.2: Employment by PXA in the GSE

Sectoral Distribution

Total employment can broken down in a variety of ways using the Standard Industrial Classification (SIC) codes. These codes are available with four levels of precision and are designed to be hierarchically nested. At the highest level (labelled with letters, though they could as easily be called 1-digit SIC codes), within the GSE sectors of interest there are 789,000 in manufacturing (SIC D); 653,000 in transport and communications (SIC I); 2.63 million in banking, finance, insurance, and real estate (SIC J, K); and, finally, 566,000 in other services (SIC O, P, Q). However, to explore the more finely-tuned hypotheses advanced over the course of the literature review we will need to drill down into the finer employment divisions.

The 3-digit SIC codes may offer a good balance between generalisation and specificity, but the 4-digit level will be particularly useful for illustrating some particularly important points regarding location choice. Table 7.1 shows how these SIC codes have been combined to create groups that are representative of the three principal Knowledge Bases we considered in Chapter 5. A full list of the relevant SIC categories can be found in the Standard Industrial Classification on page

489.

Table 7.1: Top-Level Groups

Name	Details
Symbolic	744 (Advertising), 921 (Motion Picture & Video), 922 (Radio & Television), 925 (Library, Archives & Other Cultural)
Synthetic #1	651 (Monetary Intermediation), 652 (Other Financial Intermediation), 660 (Insurance & Pension), 671 (Auxiliary to Financial Intermediation), 672 (Auxiliary to Insurance & Pension)
Synthetic #2	7411 (Legal), 7412 (Accounting), 7413 (Market Research), 7414 (Business and Management Consultancy), 7415 (Management of Holding Companies), 7420 (Architectural & Engineering)
Analytical	721 (Hardware Consultancy), 722 (Software Consultancy), 723 (Data Processing), 731 (Natural Sciences R&D)
Material Flows	D (Manufacturing), I (Transport & Communications)
Immaterial Flows	7486 (Call Centre Activities), 7230 (Data Processing)

The higher-level groups reflect the Knowledge Bases typology explored in Chapter 5 (see page 166) and are, accordingly, labelled Symbolic, Analytical, and Synthetic. Because the Synthetic grouping contains Finance as well as APS-type activity, it is much larger than the other two bases and so has been unbundled to illustrate particular points made in the The Knowledge Economy chapter regarding face-to-face interaction (F2F) and multilateral communication for synthetic firms. Finally, with a view to testing the impact of ubiquity in the flow of standardised goods and services, I created separate Material and Immaterial Flow groups containing manufacturing, call centre, and data processing employment.

We can also use the 3-digit and 4-digit codes to distinguish between different types of logistical or financial activity and merge employment across some of the larger divisions in order to create custom sub-groups. So in addition to the bases listed above sectors, I also developed several compound groups with which to further explore the patterns of activity predicted in the Methodology. The categories set out in Table 7.2 are designed to reflect the predicted variation in interaction needs within each knowledge base that was set out in the Hypothesis Generation section (page 210). In all cases, the Location Quotients (LQs) were calculated by summing together employment for each of the individual sectors and then dividing, as with simpler LQ values, by total employment in each PXA.

The finer-grained groups are designed to reflect the basic divisions used by globalisation researchers studying world cities (see Table 6.1 on page 213); amongst these are: Advanced Producer Services (APS[1]), Information & Communications Technology (ICT), Research & Development (R&D), Cultural Activity, and Logistics. However, to try to tease out more fine-grained differences, there are several additional groups that are nested within these; the higher-level APS group contains two subgroups: the Legal and Accountancy group and a broader 'Consultancy' group and, similarly, the Cultural Activities group contains a

[1] Although the 2nd Synthetic group might appear to be defined in the same way as the APS group, it should be noted that the 3-digit SIC groups contain more than the 4-digit sectors included in the calculations.

Table 7.2: Lower Level Groups

Name	Details
Logistics	6311 (Cargo Handling), 6312 (Storage & Warehousing), 6321 (Other Support Land Transport), 6322 (Other Support Water Transport), 6323 (Other Support Air Transport), 6210 (Scheduled Air Transport), 6220 (Non-Scheduled Air Transport), 6110 (Sea & Coastal Water Transport), 6120 (Inland Water Transport), 6010 (Transport via Railways), 6024 (Freight Transport by Road)
Financial Services†	651 (Monetary Intermediation), 652 (Other Financial Intermediation), 660 (Insurance & Pension Funding), 671 (Auxiliary to Financial Intermediation), 672 (Auxiliary to Insurance & Pension Funding)
ICT	7210 (Hardware Consultancy), 7221 (Publishing of Software), 7222 (Other Software Consultancy), 7240 (Data Base Activities)
R&D	7310 (Natural Sciences Research)
Legal & Accountancy	7411 (Legal), 7412 (Accounting)
APS	741 (Legal, Accounting, etc.), 742 (Architectural & Engineering), 744 (Advertising)
Consultancy	7413 (Market Research), 7414 (Business & Management Consultancy), 7415 (Management of Holding Companies), 7420 (Architectural & Enginerring)
Cultural Activity	921 (Motion Picture & Video), 922 (Radio & Television), 925 (Library, Archives & Cultural Activity)
Cultural Production	9211 (Motion & Video Production), 9212 (Motion & Video Distribution), 9220 (Radio & Television), 9231 (Artistic & Literary Creation), 7440 (Advertising)

† This is the same composition as Synthetic Group #1.

'high-value' Cultural Production subgroup that includes those working in Advertising.

Table 7.3 makes clear the unevenness in employment distribution across the three regions that make up the GSE. So, only 29% of Logistics employment falls within the London metro area, but 70% of Cultural Activity employment does. And although two-thirds of Material Flows employment, and nearly four-fifths of R&D, are based in the GSE, Financial Services work is very much the opposite since 61% of workers can be found within the London metro area. We will explore these groupings in more detail in subsequent sections.

Constraints

Because of the sampling method used to collect NOMIS employment data, the more specific the industry of interest, the greater the likelihood that available data may fail to adequately capture the scale and distribution of employment. This issue is particularly relevant in the case of fast-evolving sectors, or in the case of sectors where certain types

Group	London	GSE	Percent Central
Total Employment	**3,987,780**	**9,849,160**	**40.5%**
Symbolic	104,671	157,657	66.4%
Synthetic 1	314,108	513,052	61.2%
Synthetic 2	309,420	528,640	58.5%
Analytical	87,121	202,784	43.0%
Material	504,600	1,441,280	35.0%
Immaterial	7,320	21,000	34.9%
Logistics	72,080	246,300	29.3%
ICT	83,720	161,960	51.7%
R&D	12,600	57,440	21.9%
Legal & Accountancy	136,620	200,860	68.0%
APS	365,612	688,215	53.1%
Consultancy	172,800	327,780	52.7%
Cultural Activity	72,840	104,442	69.4%
Cultural Production	95,240	117,720	80.9%

Table 7.3: Selected Sectoral Breakdown of Employment in London and the GSE

of differentiation between activities were not previously understood or fully appreciated by data collectors. For instance, hedge funds, which are now seen as integral to London's financial services activity, seem to have been lumped in with 'Activities auxiliary to financial intermediation not elsewhere classified' (SIC 6713), but there are indications that in some cases they may also be found under 'Other financial intermediation not elsewhere categorised' (SIC 6523). Similarly, does 'Data processing' (SIC 723) describe a skilled profession (such as that performed by database mining firms), or the less skilled set of tasks increasingly performed by low-cost staff in India?

7.3 *Call Data Overview*

In order to answer the second set of hypotheses about communication patterns, we will also need to turn to patterns of phone usage. Since this terrain is largely unmapped, it is sensible to begin with the 'big picture' and then, over the course of this chapter, narrow the focus progressively towards the specific. So, for comparative purposes, this section explores the ways in which world cities such as London and New York interact with the rest of the globe and with their respective hinterlands, not only in terms of the magnitude of the flows, but also their timing, and we will see how these provide important clues to the nature of the activity occurring within each PXA.

Spatial Aspects

GLOBALISATION OF CALLING: In their focussed qualitative research, Wellman and Tindall (1993) found that the relationship between call frequency and call duration tends to vary with geographical distance:

we call most those who are closest, but speak longest to those who are further away. In data of the scale captured here, this relationship is (understandably) less immediately evident: Figure 7.3 shows the number of calls (7.3a) and number of minutes (7.3b) for traffic that began or ended on a landline in London or New York.

In effect, we are here comparing the diversity of calling for these two cities at the continent-scale. The extent to which London's flows are dominated by its interactions with Europe is stunning: for both metrics, communications with continental Europe are more than the rest of the world *combined*! Also striking is the imbalance between London and New York in terms of communications with Central and South America; although we might have expected New York City to have proportionally stronger ties, the difference is enormous.

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(a) Calls

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(b) Minutes

Figure 7.3: Normalised International Landline Traffic

An additional surprise is the differing proportion of calls to and from Asia—New York places far more on a normalised basis than London—which is altogether unexpected given Britain's long association with former colonies there and the city's temporal overlap with the Asian stock markets. This finding may fit with a broader piece of research by Barnett and Choi (1995, p.255) which found that global telecommunications interactions, as measured by bandwidth usage, tended to break down into three groups of well-interconnected regions—Latin America, Europe, Asia/Southwest Pacific—linked by a common American (or North American?) hub.

On the surface of things, although this comparison should handled with some care, it nonetheless appears to confirm similar findings by Ratti (2008, p.9)—drawn only from Internet Protocol (I.P.) data—that New York may, 'communicationally' at least, be the more cosmopolitan of the two cities. Or, at the very least, we can say that its flows are relatively less dominated by one particular set of contacts. However, we must also recognise that the number of calls and the number of minutes sampled from the British network are more than four times those sampled from the American one, and so it is possible that the

American telecommunications company is providing only a partial view of New York's total activity.

Direction & Duration: Historically, the disaggregation of inbound and outbound calling hasn't been possible, but what Figure 7.3 makes clear is that, in aggregate, the differences are fairly modest. Moreover, common sense dictates that the distinction between 'inbound' and 'outbound' cannot be that important since phone communication requires two (or more) people to participate simultaneously and in real-time. This is a very different communications dynamic from the asynchronous capabilities of, for instance, email.

Moreover, we can't use call initiation—*i. e.* who placed the call—to determine whether someone is 'giving the orders' or is 'receiving the instructions': a junior employee might be ringing to ask 'what should I do next?' or a senior staff member might be calling to ask 'have you finished the project yet?' In short, in most cases it will be sensible to work with the sum total of calls or minutes and to ignore directionality.

Figure 7.3 also serves to emphasise another aspect of telecoms usage that will be useful to our analysis: that while the specific relationship between aggregate calls and minutes along any one link vary, they nonetheless tend to vary in tandem. So even if the exact relationship between calls and minutes for any one link is unpredictable, the obvious implication is that more calls naturally entail more minutes of communication. We can also approach the issue in a pragmatic manner by assuming that some proprotion of calls might be a mis-dial, an unwanted communication ("We'd like to make you an offer…"), or a cost-related behaviour ("Call me back…") of some kind; however, this effect will have less impact on the number of minutes between locations since these communications will tend to be quickly terminated.

Consequently, working with minutes will tend to reduce the impact of marketing call centres and other activities that involve a lot of calls but not much actual 'communication'. Moreover, if we return to the thinking on knowledge-intensive work set out in Chapter 5 then it seems *likely* that more complex information and more intensive interactions will require more time to communicate. There is a risk that this approach will emphasise long-distance links at the expense of nearby ones, but if there is a systematic bias it should emerge in the course of this analysis. Accordingly, with only a few notable exceptions, I will focus on 'minutes of talk' (also referred to as 'call volume' or simply 'calling') in preference to 'total calls' (or 'total number of calls') in this analysis.

International Calling: We know from Figure 7.3b that London and New York's international communications footprints differ in important ways. In Figure 7.4[2], although the United States is the dominant partner for communications with London—it has more than twice the number of minutes that Ireland, the next most talked-with country, does—its equally large population reduces its significance when the data is weighted with its 2005 population. Figure 7.4 highlights British

[2] See page 339 for a version using data from New York City; and see page 339 for the unweighted version of Figure 7.4.

overseas territories such as Gibraltar, the Falklands/Malvinas, and several South Pacific islands, and its colonial heritage is also obvious in the links with Africa, Australia (22% of minutes to America), Canada (17%), and India (16%).

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Figure 7.4: Normalised Call Volumes to and from London

Rather more obvious is the magnitude of intra-European flows in both absolute and *per capita* terms. The list of top 10 most talked-with countries is composed largely of European entries: Ireland (44% of total minutes with America), France (36%), Germany (34%), and Spain (25%) fill out second through fifth place on inbound, outbound, and total minutes to London. Belgium, the Netherlands, Switzerland, and (rather more surprisingly) Sweden also put in appearances in the top fifteen. There are also obvious connections to the Middle East, and in particular with the United Arab Emirates.

What is striking to me about this map of global communications is that, while it reflects the dual globalisation processes posited by authors such as Sassen (cf. 1991, 2002, 2008), it also suggests that a more nuanced understanding is required around how these processes manifest in communicational terms. Informational flows seem to be strengthened along several discrete axes: economic, linguistic, and social/historical. So the economic effect embodied in flows between global financial centres is clear—even though Japan is not particularly prominent in this 'telegeography'—and the strength of connections to countries of origin for recent migrants is also clear; however, we can also find the lingering traces of the British Empire, as well as a surprisingly strong set of trans-linguistic connections between London and the largest economies of continental Europe. Although a much more detailed analysis would be required, the magnitude of this last type of link does lend at least indirect support to a suggestion by Hall (2002b) that, in some sectors, the rest of Europe is a kind of 'hinterland' to London's economy—much as the rest of America and Canada can be considered to be to New York's—though it is also undoubtedly connected to migration through visa-free intra-EU migration (see also Ratti, 2008, p.9).

Urban Geographies: We can also look at how intensely different cities within Britain connect to the rest of the world, giving us some sense of the extent to which London, as a primate city on a nearly unparalleled scale, might be unique. Depending on where you draw the boundary, London contains nearly 1-in-5 people in Britain, so it is not just more people, more firms, and more activity, it is *vastly* more people, firms, and activity. Consequently, a straightforward 'percentage of all flows' comparison between British cities, similar to the one for Australia found in Graham and Marvin (1996, pp.133–134) or to the figures in de Goei et al. (2009), is largely meaningless.

Figure 7.5: Percentage of International Minutes and Phones (Top & Bottom 10 British Cities)

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Figure 7.5 illustrates the magnitude of the problem: the London defined by the 'Larger Urban Zone' (LUZ) accounts for 37% of *all* international minutes to or from landlines in Britain (35% of inbound and 38% of outbound)[3], and the next biggest LUZs are Manchester (3% of minutes) and Bradford-Leeds (2%). Narrowing the focus does not fundamentally alter this structure: at the Urban Audit area (UA) scale London still accounts for 27% of all international minutes, while Birmingham is a distant second at just over 1%. These findings lend strong empirical support to a claim by Graham (2002, p.77) that:

[3] This number *includes* calls not placed or received within an LUZ—if we exclude non-LUZ minutes then London's dominance rises to 60% of all international calls to or from LUZs.

> It is important to stress that global cities dominate much broader realms of telecommunications activity than those usually addressed in global cities literature: financial services, corporate finance, and trading. Such is their concentration…that global cities also dominate phone, mobile phone, media communications, and Internet use outside the corporate and financial sectors.

This difference in scale means that it is helpful—and indeed necessary—to normalise the raw totals extracted from the data with a measure of how many people there are in each area to actually place or receive calls. Normalising the data can mask the importance of the very largest flows in absolute terms, but it also enables us to develop a more finely-tuned understanding of areas that are punching above, or below, their weight in terms of communications activity.

Regardless of how exactly we treat the public exchange areas (PXAs)—*i. e.* separately or as groups within towns and cities—we have several choices for normalising the calling data: 1) within England and Wales we can divide the results by the number of residents in a PXA; 2) we can divide the results by the sum of workers and residents; or 3) we can divide by the number of active phones in the area. The first option would emphasise areas dominated by industrial activity because these tend to have smaller populations (*i. e.* a smaller denominator); the second option would tend to underemphasise urban PXAs by double-counting people in dense, mixed-use areas (*i. e.* a larger denominator); and the third option may marginally over-emphasise areas dominated by residences because these may, on average, have more distinct phone numbers per person than a business-dominated area (especially areas dominated by large businesses).

However, this last option also enables us to examine the entire U.K. since, unlike the Census data (which has not been joined to the exchange geography of Scotland), this metric is embedded in the data itself. The results from this type of normalisation of international calling data are presented in Figure 7.6. This approach reduces the 'London effect' and highlights the range of calling behaviours across the country: Stoke-on-Trent makes less than 20% the volume of international calls that Bracknell does on a *per phone* basis. Significantly, we now find that every Urban Area (UA) in the top ten 'most international' group can be found in the GSE. The first city from outside the GSE is Warwick (13^{th} place), and Liverpool (15^{th} place) is the first major city not from the South in the list.

Interestingly, the least international cities contain a mix of deprived and comparatively well-off areas: Stoke-on-Trent and Middlesbrough might be expected to show little evidence of international linkages, but Exeter, Plymouth, and Swansea are rather more of a surprise. Taken with caution, this figure appears to imply that on an aggregate level the relationship between information flows and deprivation may be quite complex, possibly even more so than was suggested by the social network analysis undertaken by Eagle et al. (2010), which focussed only on domestic calling behaviour as it relates to deprivation.

Figure 7.6: Normalised International Minutes per Phone (Top & Bottom 10 British Cities)

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Domestic Calling: Because the data covers an entire country, we can investigate not only how London interacts with other British cities, but also how those other cities interact with one another. This second dimension will be pursued in more depth near the end of this chapter, but Figure 7.7 provides an interesting comparison of call volumes, normalised by the number of phones in the counterparty city[4] for London, Manchester, and Stoke-on-Trent. Maps of the total volumes scaled against the largest flow can be found on page 346.

In the case of London, although the influence of major cities is clear—Birmingham is the most talked-to city, with Manchester a fairly distant second—when we normalise against the number of phones we actually see a preponderance of regional calling: smaller cities nearby receive far more calls on a *per phone* basis than larger, more distant ones. If we look at Manchester's pattern of calling activity, then although London is by far the dominant *absolute* flow, after normalisation it is the local links to areas such such as Stockport, Diggle, Marple, Longdendale, and Salford that dominate. Stoke-on-Trent shows a similarly distribution: London is again the dominant unweighted link, with Birmingham, Crewe, Manchester, and Market Drayton rounding out the top five, but following normalisation it is the local geography that matters.

Domestically, the importance of London is at least in part a function of its massive population; however, Figure 7.8 adds to our understanding of how this changes when we consider the average number of minutes *per phone*. In comparison to Figure 7.6 above, the totals are much larger: the difference between the highest domestic phone use in

[4] So each flow was divided by the population of the city with which the city-of-interest if speaking: so in the 'London Map' we divide calls to/from Stoke-on-Trent by the number of active phones in Stoke-on-Trent, but in the 'Stoke-on-Trent Map' we divide calls to/from London by the number of phones in London. In cleaning the data underlying these figures, some centres of telemarketing activity (*i. e.* Christchurch and Rothbury) were identified and suppressed, although this did not prove necessary in the subsequent TQ and eigenplace analyses.

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Figure 7.7: Normalised Call Volumes to/from London, Manchester & Stoke-on-Trent

Maidstone and the lowest in Stevenage is vastly greater than the largest international average in Bracknell. And yet, on a percentage basis the difference is much less: 200% between greatest and least number of domestic minutes, compared with 700% for international traffic.

Interestingly, the top ten in Figure 7.8 have nothing in common with either the top or bottom callers from the international league table, while the bottom ten are a mix of both ends from Figure 7.6. More research would be required to fill in this picture, but it seems that different processes may be at work here: some areas are more 'plugged in' to international flows in a way that reduces their local connectivity or, at least, does not stimulate it (*e.g.* Cambridge, Luton, Oxford, and Reading), while others areas may simply talk less, full stop (*e.g.* Middlesbrough and Exeter).

Temporal Aspects

We've looked at the spatial component of communications usage, but examining the temporal dimension will help us to understand how the cycles of calling help to define the spaces and places of information flows. As we saw in Figure 6.10 (see page 234 in the Methodology), there is a strong weekly cycle in telecoms usage with a peak during the working week and marked drop-off over the weekend; however, in that figure we did not attempt to distinguish between different types of usage. So although the findings below are in line with results from a range of other cities and telecoms sources and are not particularly 'new' (cf. Reades et al., 2007, 2009), understanding them is nonetheless important for this analysis, and in particular to understanding how the eigenplaces analyses will function later in this chapter.

In order to show how different areas have different temporal signatures that can be used for categorisation purposes, I arbitrarily selected several 'neighbourhoods' to profile in London: Central London, Ealing, and North London/Enfield[5]. Each of these areas has a different

[5] Croydon, which was not measurably different is shown in the appendix. I also chose neighbourhoods in New York: Lower Manhattan/Wall Street, Upper Manhattan/Inwood Hill Park, East Corona/East Elmhurst, and East Flatbush/Prospect Park South; the results for these areas are reported on page 348.

Figure 7.8: Normalised Domestic Minutes per Phone (Top & Bottom 10 British Cities)

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makeup, though one area is obviously the traditional CBD while the other three are predominantly residential areas. The idea is to show that there are some underlying commonalities alongside some major structural differences in terms of how the use of telecoms varies in each place.

Domestic Call Timings: We can begin by comparing the average number of domestic calls for each hour of the day over an entire week, as shown in Figure 7.10. In all cases the scale has been removed to protect confidential operator data, and is *not* the same across all of the locations shown. This figure provides strong evidence in support of the idea that there are important behavioural differences between neighbourhoods: Central London is obviously following a very different pattern of activity from North London and Ealing. Wireline calls show dramatic fall-offs over the weekend in the business-dominated area—on average, more than 80%—and a prominent double-peak on either side of the lunch hour when compared with more residential areas. The residential areas also show a much slower decay in calling activity in the evenings, whereas in Central London calling falls off quickly after 5 p.m.[6]

Although one might reasonably expect that plotting the average number of minutes over the same time period would provide much the same information as the average number of calls, but in Figure 7.11 we actually see something quite different at this finer scale. In the first place, there is an increase in the number of minutes to and from Central London at 10 p.m. that is not reflected in the number of calls. Given

[6] Data for New York City, which show a similar pattern of activity, are available on page 348, and that section also shows the relationship to aggregate international calling for both cities.

Figure 7.9: Location of Selected Neighbourhoods

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Figure 7.10: Number of Domestic Calls in London

that this coincides with the close of markets in New York (5 p.m. EST), it is possible that the surge is connected to the type of 'synchronisation' activity described by Clark and Thrift (2003) in the financial services sector, though this would be implying a domestic inter- or intra-bank process. The other obvious features in North London and Ealing are: first, the increase in minutes after 6 p.m. (even as the number of calls continues to fall); and, second, the way that weekend and weekday minutes track each other quite closely (at least, they do compared to what happens in the CBD).

What these trends reinforce is the idea that, to some extent, we can distinguish between residential and business areas based *solely* on the timing of calls. As well, the contrasts between Figures 7.10 and 7.11 emphasise that while both calls and minutes could be used to examine behaviour differences, the minutes plots demonstrate more substantive variation. In sum, based on the information gathered so far it is possible that, armed with nothing more than weekend and weekday usage patterns, we could laboriously create a map of Great Britain's business and residential areas.

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Figure 7.11: Volume of Domestic Calls in London

Sassen (2008, p.10) suggested that "…at the top is increasingly, though not fully, a permanent twenty-four hours of talking, with rapidly shrinking 'nights'", but again we see that the situation is a good deal more nuanced: the 'nights' are *not* shrinking, nor are City and Wall Street workers giving up their evenings and weekends for ever-larger bonuses. It is possible that, on weekends, this activity shifts to other platforms (*e.g.* mobile), but the way in which usage here tracks market openings and closings suggests that this may only be the case in a limited way. There is also intriguing evidence of activity that falls outside of the regular workday bounds, but exploring that would require more detailed investigation than is possible, or appropriate, here.

INTERNATIONAL CALL TIMINGS: For Figure 7.12 I have rescaled international and domestic volume to make it easier compare differences in the patterns of usage between the weekends and weekdays for the CBD and one residential area in each of London and New York City[7]. Clearly, the rescaling adds noise to the figures (especially for 'Lower Manhattan Weekend' and 'Central London Weekend'), but it also highlights the commonalities: both CBDs have very similar patterns of domestic calling, and the overall trend for international calling is similar, save for the difference over the lunch hour. In residential locations, the clear trend is for the number of minutes used in the evening to match or exceed the daytime peak, a very different pattern from the business locations.

On a final note, Figure 9.4, on page 343, records a fascinating moment in history: the near collapse of the global financial system in September of 2008 discussed in Chapter 3 (see page 94)[8]. Broadly speaking, on Wednesday the 17th and Thursday the 18th the massive increase in outbound calls (amounting to a 120% increase over normal

[7] To compare the two cities in the format used above please see page 353.

[8] A helpful day-by-day timeline can be found at `http://en.wikipedia.org/wiki/-September_2008-#2008_September_17`

Figure 7.12: Comparison of Normalised Volumes in London and New York

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(a) Weekday International

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(b) Weekend International

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(c) Weekday Domestic

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(d) Weekend Domestic

levels), and the smaller increase in minutes (roughly 110% of normal), mark the onset of the crisis in the financial markets when the Dow Jones Industrial Average fell by 440 points on fears of AIG's imminent collapse. However, notice too that while the impact is most visible in outbound calling, inbound international calling shows a more gradual but equally significant rise over the two weeks following the crisis.

Summary

We began this chapter with an exploration or international calling activity and, tentative though the conclusions must necessarily be because of the scale at which we've been examining the data, we found evidence to support the idea that calls are driven by three types of homophily (Lee et al., 2007, p.418); or to put it in the terms that I have used in Chapter 5 (see page 177), three types of proximity: geographic, social/historical, and economic (cf. Barnett and Choi, 1995; Barnett, 1999). In the case of London, there is clear evidence of the importance of the economic and geographic proximity of continental Europe, and of the historic importance of the former colonies, but the strongest links observed in the data stems from the confluence of all three factors. Similar data for New York City alters the picture in subtle ways, since the notion of geographic proximity is clearly relative—it is further from New York to Toronto than from London to much of the rest of Europe, but the flows are, proportionally, still very high.

Taking in the broader picture of phone usage in Britain, the level of calling varies significantly, and proximity to London is a clear predictor of the internationalisation of activity. The same was not, however,

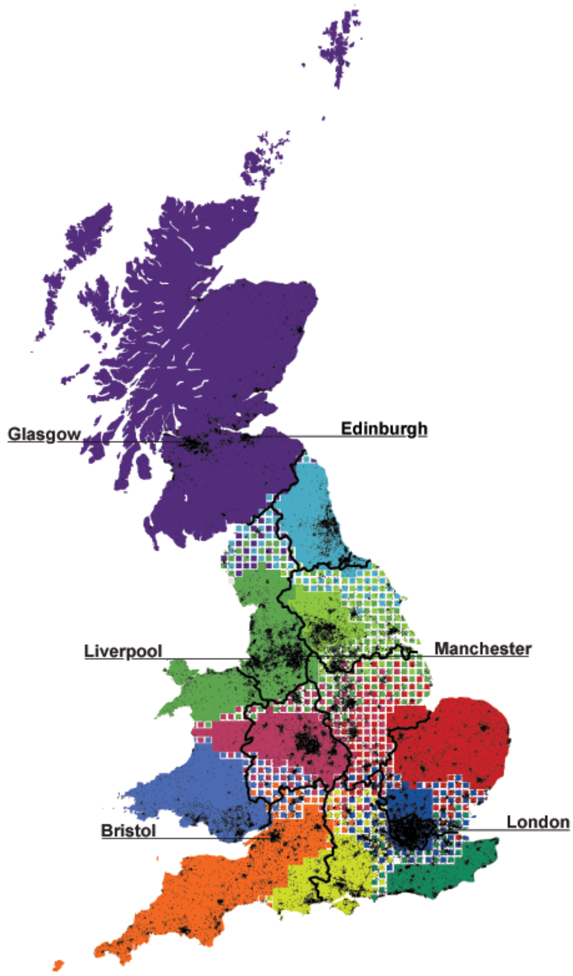

Figure 7.13: Regionalisation of Britain using Social Network Data (Ratti et al., 2010; reproduced under Creative Commons Attribution License)

found to be true of domestic calling in Britain: London actually falls in the lower half of a ranked, normalised list. We did find indications that regionalisation exists, and that calling is distributed according to specific social and economic dynamics. This result is broadly consistent with more detailed evidence advanced from a social network analysis (Ratti et al., 2010), and it is clear that such data puts paid to the persistent notion that the costlessness of long-distance communications means that distance is 'dead'.

Incorporating the temporal aspect of telecommunications usage allowed us to flesh out the portrait of telecoms usage developed in previously-published works (cf. Reades et al., 2007, 2009; Calabrese et al., 2010). The prominent double-peak on either side of 2 p.m. seems, in the main, to be more closely connected to business activity than to residential; but more interesting from the standpoint of being able to characterise spaces using telecommunications is the fact that international calling activity varies dramatically between residential and business areas. The data from New York also fills in the picture of what might be happening with mobile phone usage in terms of international calling: it shows a distinct surge in the post-9 p.m. 'free weekends and evenings' period even though international calling is not covered by such plans. Logically, it is therefore connected to the timezone of the people being called and to particular patterns of social reproduction and historic migration.

The results from this section also emphasised the importance of data normalisation to aid with interpreting the data. For instance, although America is the dominant communications partner for London, this *has* to be contextualised by the fact that there are more than 300 million Americans with whom Londoners can speak. Similarly, although the importance of links between the Caribbean and New York City is already evident in the raw data, after normalisation the relative importance of the region is much more clear. And this issue applies domestically as well: taking the number of phones as a baseline enables us to identify less obvious, but no less significant, flows buried within the dominant absolute ones. So while is is perfectly accurate to think of London as dominating Britain's telecommunications activity, this is not necessarily helpful since it transpires that other parts of the country use their phones relatively more than London does.

7.4 Globalisation

Telecommunications Quotients

We have developed a high-level understanding of distribution of spatial and temporal calling activity, and it is now sensible to turn to a more detailed geography in order to begin investigating the internal functioning of London and the GSE. We will begin with the simpler Telecommunications Quotient (TQ), before turning to the full-fledged eigenplace analysis. In both cases we will use only aggregate international and domestic traffic, since this coarsest grain should provide us with an immediate indicator of the utility of each approach.

LONDON: The small size of exchange areas and high level of functional specialisation in London contribute to a dearth of normally-distributed data when we convert the total number of minutes for each PXA to a TQ. However, the distribution is much wider, and much more obviously skewed, in the case of international calling. In other words, while London is, on average, much more international in its calling behaviour than the rest of the U.K., this globalisation of activity is not distributed evenly across the metro region. A small number of PXAs account for much of this total call volume: the PXA with the largest volume of international calling uses 14× as many minutes as the area with the least, although the *per phone* difference is 'just' 2.7.

In effect, Figure 7.14b provides a partial view of globalisation by comparing the level of international calling minutes to the total amount of calling at the exchange area scale. The figure shows a marked East/West gradient: many areas in the East (Barking & Dagenham, Havering, etc.) and the South (Bromley, Bexley, and to a lesser extent Croydon) have relatively low international TQs, but these values rise as we move Westwards. The most visible international areas in Figure 7.14b are clearly intimately associated with Financial Services activity in

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(a) Domestic

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(b) International

Figure 7.14: London TQs

the City and Canary Wharf, as well as with the activity of sectors such as Advertising and Government/NGOs in the West End, Westminster, and Kensington.

GREATER SOUTH EAST OF ENGLAND: At the larger scale of the GSE call volumes are still not normally distributed across the relevant areas of analysis. In Figure 7.15a there are just a few areas that generate vastly greater levels of international traffic as a proportion of their total communications activity. Here we begin to see a regional knowledge economy in operation—particularly if we focus on the top two categories (*i. e.* the 1.95–3.23 and 3.24–8.04 ranges)—in terms of the levels of global information exchange across a geographic area containing more than 20 million inhabitants. What is particularly promising about these TQ maps, however, is that they appear to map neatly neither on to total levels of employment (Figure 7.2a), nor on to the employment ratio (Figure 7.2b), which suggests that we are picking up on something different.

Especially evident in Figure 7.15a is the high level of international calling activity along the M4 and the edge of the M25—in Figure 7.14b we could only see hints of the full scale of this activity to the West and Southwest. Although there is a secondary grouping of intense international activity around Cambridge, it is really the 'Western Wedge' running in an arc between, roughly, Guildford and Amersham that is the central feature here. In addition, the area surrounding Milton Keynes should also garner our attention: its lower levels of international calling activity are quite noticeable when compared to the activity out towards Reading and Bracknell. This result is consistent with Milton Keynes being a more minor, back-office node in the APS networks examined by the GAWC group (cf. Pain and Walker, 2005; Taylor et al., 2009).

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(a) International

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(b) Domestic

Figure 7.15: GSE TQs

Eigenplaces

THE GREATER SOUTH EAST OF ENGLAND: Figure 7.16 presents tripartite clusterings of the GSE based on international (Figure 7.16a) and domestic (Figure 7.16b) call volumes normalised by the number of phone in each PXA. In both cases, the darkest colour connotes the highest *average* signal over the course of the week, and the lightest colour the lowest average. Note that, because of the way that the analysis works, this does *not* mean that all PXAs in, say, Cluster #2 of Figure 7.16a have higher peaks than all PXAs in Clusters #1 and #3, merely that the mean suggests that there are more PXAs with larger call volumes in this cluster.

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(a) International Volume

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(b) Domestic Volume

Figure 7.16: International & Domestic Eigenplaces (Volume/Phones)

The silhouette plot for the international data (Figure 7.17) suggests a mixed clustering result: Cluster #1 forms a particularly coherent group of PXAs, whereas Clusters #2 and #3 contain some PXAs that are poorly clustered. Consulting the representative signals (see Figure 11.20 on

440) explains this classification: Cluster #2 contains PXAs will radical variation in the overall level of international calling activity, and in particular in the magnitude of the afternoon rise in call volumes; Cluster #3 is more poorly clustered less because of differences in magnitude than because it tends to contain PXAs with very different patterns of activity over the course of the day.

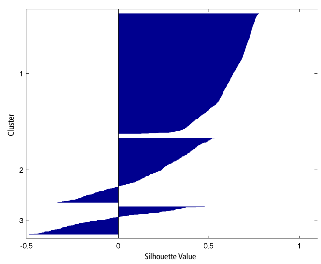
There are several notable features of Figure 7.16a that merit further discussion: first, the strong Westward bias of international calling is particularly obvious, as is the fact that East Anglia generally has lower *per phone* levels of activity; second, is the existence of small internationally-oriented clusters around each of the major outlying cities (Oxford, Milton Keynes, Cambridge); and third is the fact that domestic *per phone* calling has no obvious links to either urban or industrial hierarchy. However, the more important, underlying conclusion here is that international and domestic calling are *not* correlated when processed in this way: if we were to find that the areas that made the most international calls on a *per phone* basis *also* made the most domestic calls then this would tend to imply simply that some areas called more than others; instead, we see here that there are marked differences in calling behaviour at the *same* PXA that will undoubtedly be useful when we use both data sets in the classification process.

As well, there is a clear extra-metropolitan link between high levels of international calling and two very particular sets of activities—transport and defense—and especially with areas connected to inflexible network nodes such as ports and airfields/airports. It is also worth remarking that Cluster #2, which represents lower overall calling activity, is concentrated in East Anglia, suggesting that beyond Cambridge much of this area is relatively domestic in its orientation[9]. Juxtaposing Figures 7.16a and 7.16b highlights the very different nature of the two types of calling data: the structure that is so self-evident in international calling is largely missing from the domestic call data, and this emphasises the fact that although the clustering process is influenced by the density of people and activity, it is not dominated by them.

At the GSE scale we can also iteratively exclude data that is extraneous to the behaviour of interest, progressively narrowing the focus until only those areas that are of interest are retained. For example, taking only calls to America we could first use an eigenplace analysis to partition the PXAs into two subsets—one with typically high-volume usage and one with typically low-volume usage—and then take *only* the high-volume areas as the input to a new eigenplace analysis that would tease out finer-grained details in the timing and magnitude of flows. Repeating this process with the silhouette tests as a guide would gradually tease out finer and finer distinctions (and more and more partitions) until the differences cease to be meaningful and all that is left is essentially noise.

[9] The notable exceptions are R.A.F. Lakenheath, R.A.F. Mildenhall, and their surrounds, the existence of which can also be easily inferred from the 2001 Census data. This does, however, seem like a prudent time to repeat the statement that it is impossible to trace calls to individual users within these data sets and that one objective of this research is to demonstrate the ability to perform commercially and academically valuable parametric analyses on call data in a way that does not pose a privacy or security risk.

Figure 7.17: International Volume Silhouette



Summary

We have now taken a first look at the ways in which telecommunications can be used to map out industrial activity at the urban and regional scales. We have also briefly examined international and domestic usage, and seen how these provide clues that enable us to decipher the once enigmatic spatiotemporal signatures. As well, an initial exploration of international calling has picked up several geographic areas known to be associated with the process of globalisation, especially the City of London and the West End.

One issue that we encountered with the use of the TQ, and with TQs derived from international data in particular, is that as we broaden the base region R, deviations from the expected overall regional mean of 1 became worse, and the overall distribution *less* normal! In this sense, directly equating the LQ to the TQ is problematic; however the difficulties with non-normality do lend definite empirical support to Castells's claim that "[much] of the 'global city' is actually quite local (*e.g.* Queens, Hampstead or Brixton) except for their immigrant populations" (2009, p.7).

As well, because the TQ lacks a temporal dimension, we cannot distinguish between, say, calls that are influenced by familial relationships (in which case there should be more calling on weekends) and those that are influenced by business relationships (in which case there should be more calling during the period between 9 a.m. and 5 p.m. on weekdays). That said, the TQ is nonetheless very easy to calculate, enabling analysis to be performed in aggregate and without the need for complex technical applications or infrastructure beyond the reach of basic social science. Significantly, the TQ also yields a scalar value that is potentially suitable for comparative analyses.

The eigenplace approach addresses the gaps noted with the TQ, and the geography that emerges from a simple analysis of international calling seems to capture very quickly the overall urban hierarchy. This is possible because the decomposition and clustering approach not only factors in the scale of the calls to and from each PXA, but also gives weight to the similarities and differences between the ebb and flow of these interactions. But what the structure extracted in Figure 7.16 does make clear is that naïvely including *all* PXAs from within the GSE means that major differences—such as those between residential and business calling cycles—swamps the differences *within* the business category, and so a more sophisticated method is required.

7.5 KDDi and Location Filtering

So in spite of the capabilities of the TQ and eigenplace approaches, we still face the challenge of extracting a meaningful signal from a great deal of background noise: amongst the more than eight billion phone calls are all manner of personal and professional communications, but in this analysis we are only interested in the latter. So we need to narrow the focus of the analysis to only those PXAs that we have reason to believe are involved in a particular type of industrial activity. There are two obvious ways to do this: by the characteristics of the caller, and by the characteristics of the place from which calls are placed, or at which they are received.

Filtering on Call Volumes

To date, the majority of social network research either ignores the impact that business networks have on their results entirely, or simply subsumes them under a generic 'social interaction' label. Only the GAWC group at Loughborough has explicitly tackled the network characteristics of professionals in different sectors (cf. Taylor and Walker, 2001; Taylor et al., 2006, 2008, 2009). However, in the rich data set available for Britain, we can actually segment callers into different groups using the aggregate volume to and from each anonymised number, and then use this to draw inferences about the impact of globalisation and scale on businesses of varying sizes.

Table 7.4 sets out the categorisation developed in order to filter out the least frequent users of landline connections: each group interval is double the one below it, rising from a base average of just 30 minutes a day, up to more than 256 *hours* of talking every day, including weekends! This approach has the advantage of reducing the noise of the overall system dramatically; however, it should also be noted that non-geographical numbers (*e.g.* 0800-numbers) cannot be included in this approach for obvious reasons and that, depending on the exact configuration, firms where each employee has a separate number *may* not be included amongst the large volume users.

Category Name	Monthly Threshold (Seconds)	Caller Group	Percentage of All Callers
Less Than 30 Minutes per Day	55,800.00	Household & Small Business 1	*Suppressed*%
Less Than 1 Hour per Day	111,600.00	Household & Small Business 2	*Suppressed*%
Less Than 4 Hours per Day	446,600.00	Small & Medium Business 1	*Suppressed*%
Less Than 8 Hours per Day	892,800.00	Small & Medium Business 2	*Suppressed*%
Less Than 16 Hours per Day	1,785,600.00	Medium Business 1	*Suppressed*%
Less Than 32 Hours per Day	3,571,200.00	Medium Business 2	*Suppressed*%
Less Than 64 Hours per Day	7,142,600.00	Large Business 1	*Suppressed*%
Less Than 128 Hours per Day	14,284,800.00	Large Business 2	*Suppressed*%
Less Than 256 Hours per Day	28,569,600.00	Very Large Business 1	*Suppressed*%
More Than 256 Hours per Day	10,000,000,000.00	Very Large Business 2	*Suppressed*%

Table 7.4: Caller Category Distribution

For the purposes of our analysis, it is sensible to focus only on numbers responsible for an average of more than 4 hours of calling per day because these are unlikely to be residential users. At the other end of the scale, some of the 'Very Large Businesses' may well be call centres, but they may be indistinguishable from major back-office facilities in sectors such as financial services, insurance, and telecommunications. There is strong evidence for this overlap to be found in Figure 7.18, which shows the number of Medium to Very Large callers by PXA across Great Britain: Leeds, Glasgow, and Liverpool are all particularly prominent, and these cities are also associated with large telecoms facilities[10]. From this point onwards, the results will all be drawn from a data set that excludes the two groups of users who make the least use of telecommunications.

[10] For privacy reasons, PXAs containing fewer than 5 such numbers in the relevant range have been suppressed entirely from the map.

Figure 7.18: Number of Medium to Very Large Volume Callers by PXA

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Filtering on Industrial Concentration

Filtering a wide-scale areal analysis by some measure of employment is unusual—most such analyses tend to work with contiguous regions—but since employment data is both well-understood and readily available, this is another logical filter to apply to the PXA selection process. In the subsequent sections I will use LQ values to sift out areas lacking significant employment in a particular sector or sectoral grouping, and this means that the resulting TQ and eigenplace analyses will be representative of only those areas where a particular industry or group of industries can be found. In other words, where we find meaningful communicational differences between, for instance, two groups of areas that both contain Financial Services activity then we can construe these differences to be representative of underlying differences in their operating environments.

I have defined a category of 'Significant Locations' to help focus the telecommunications analysis on just those areas where not only is there a statistically-significant concentration of activity, but there is also a significant percentage of employment in a given sector. The definition of this process is quite simple where the distribution of a group or individual sector is lognormal[11]:

$$\frac{x_{si} - \mu_s}{\delta_s} > 1.5 \quad \cap \quad \frac{Emp_{si}}{Emp_i} > 0.10$$

Here, on the left-hand side we calculate the z-score for sector s in PXA i using the mean and standard deviation of the logarithm of the LQs for sector s across the entire study area, and we require that it exceed a statistical significance threshold of 1.5 deviations from the mean. On the right-hand side we require only that at least 10% of the employees in PXA i work in sector s, although this obviously tends to mean that individual 4-digit sectors are less likely to exceed this cutoff. By taking the intersection (∩) of the two sets of PXAs we maximise the likelihood of selecting locations where the activities of a firm will leave a measurable impact on telecommunications usage.

Where the data is not lognormal, the left-most constraint must be relaxed since the standard deviation is meaningless and, accordingly, in those cases I have used the 95th percentile as the cutoff. Finally, it should be emphasised that we will be working here with areal data and not subscriber-level data, so we cannot definitively link telecommunications activity to individual firms. Nor, for privacy reasons, would we wish to do so. Although alternative approaches could theoretically enable this level of detail in the future, on a practical level this means that when we talk about the 'behaviour' of a sector we are really discussing the range of activities within a PXA where there is a high proportion of employment in that sector. Consequently, the dynamics captured below in the form of 'internationalisation' and 'globalisation' do not necessarily refer to the degree of globalisation of individual firms or sectors, and are best understood as the 'outlook' of the local *environment* in which the firm or sector operates.

[11] Note that we exclude areas with no employment in a sector from the lognormal calculation so as to avoid a left-skewed distribution with values of $-\infty$.

7.6 Symbolic Industries

Spatial Distribution

In Chapters 5 and 6 we predicted that Symbolic knowledge work would tend to involve: a particularly strong need for multilateral, F2F interaction; a relatively strong resistance to substitution by ubiquitous telecommunications; and a preference for amenity-oriented locations. We have already seen in Table 7.3 (page 256) that Symbolic workers' distribution suggests a general bias towards Central London. However, we can further subdivide the workers according to specialty, and subdivide space into four 'rings' of employment: Central London (the 'Central Activity Zone' defined in the 2004 London Plan which is, is essence, the City and West End); Inner London (the parts of the inner 12 boroughs not incorporated in Central London); Outer London (the remaining 12 boroughs of the Greater London Authority); and the Outer Metropolitan Area (those parts of the GSE which have economies widely presumed to be directly dependent on Greater London based on commuting patterns).

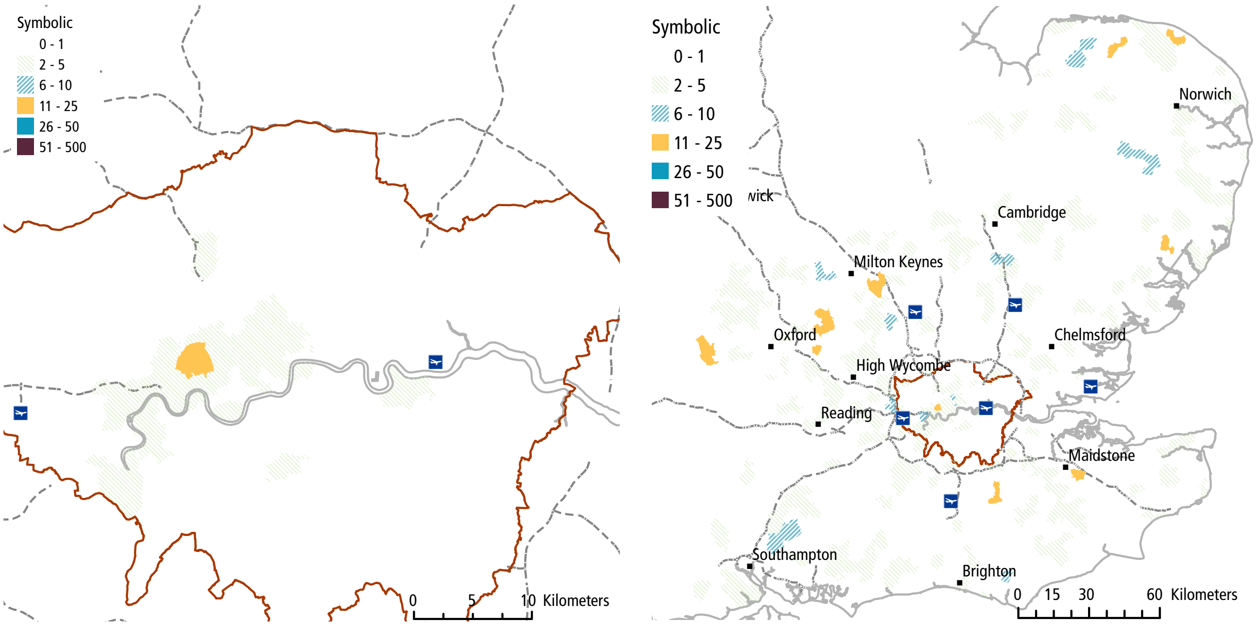
Table 7.5 shows the percentage of workers in each of the four sub-regions by SIC code. Several distinctions are immediately obvious: roughly 20% of Video Projection and Library workers are in Central London, and 60% are in the two outer zones, whereas for Arts Facilities, Museums, and Historic Buildings it is nearly the reverse. These two results are unsurprising since we'd expect consumer-oriented services to be distributed in parallel with residential densities, and major cultural infrastructure to be found mainly in the capital city. Rather more more interesting is the difference amongst high-skill knowledge workers: over 70% of news-related activity and nearly 50% of film production and distribution is centrally-located, while for radio, television, artistic and literary activities the figure is nearer to 40% and there is a much more significant proportion of employment in the next two rings out from the centre.

Sector	SIC	Central London	Inner London	Outer London	Outer Metro Area
Advertising	7440	51.2%	10.0%	15.5%	23.2%
Motion Picture & Video Production	9211	54.7%	14.6%	15.1%	15.5%
Motion Picture & Video Distribution	9212	48.1%	34.0%	11.1%	6.8%
Motion Picture Projection	9213	18.1%	17.0%	31.8%	33.0%
Radio & Television Activities	9220	39.9%	33.3%	19.7%	7.2%
Artistic & Literary Activities	9231	39.3%	20.6%	20.9%	19.1%
Arts Facilities Operation	9232	60.6%	9.2%	10.9%	19.4%
Other Entertainment	9234	34.6%	19.6%	18.4%	27.4%
News Agency Activities	9240	71.8%	19.3%	4.8%	4.0%
Library & Archive Activities	9251	20.7%	12.1%	31.2%	35.9%
Museums & Historic Buildings	9252	62.8%	4.8%	12.6%	19.9%
All Sectors		26.0%	11.0%	25.6%	37.4%

Table 7.5: Symbolic Group (adapted from Smith, 2011)

There is strong evidence here to suggest that Inner London plays an important, but less visible role than Central London in this Symbolic economy: even for highly-centralised sectors such as Film Distribution, Radio, Television, and Artistic activities there are, on average, still more than 20% of workers in each of the next rings. We can see this process more clearly in Figure 7.19, which highlights the importance of White City (near Shepherds Bush) as the centre of an axis of activity running from Soho all the way to the limits of Greater London. Pulling back to the GSE scale in Figure 7.19b, although the picture becomes more complex, it nonetheless reinforces the evolving interpretation of the preferences of firms working with this knowledge base: Symbolic knowledge workers tend to be found in a relatively small number of very highly-concentrated areas where their LQ exceeds 10, or even 20, times the regional average. That said, it is very interesting to note that these firms are more widely distributed than expected: some of the highest concentrations are outside of London.

Because Figure 7.19a is dominated by the high staffing levels of Radio and Television Activities, disaggregation of this group reveals a more



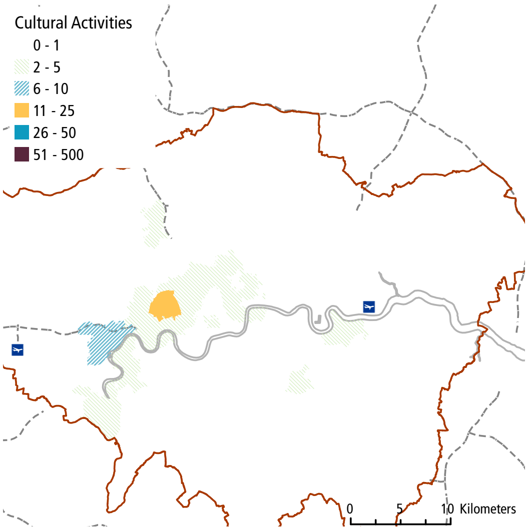
(a) London (b) GSE

Figure 7.19: Symbolic LQ Results

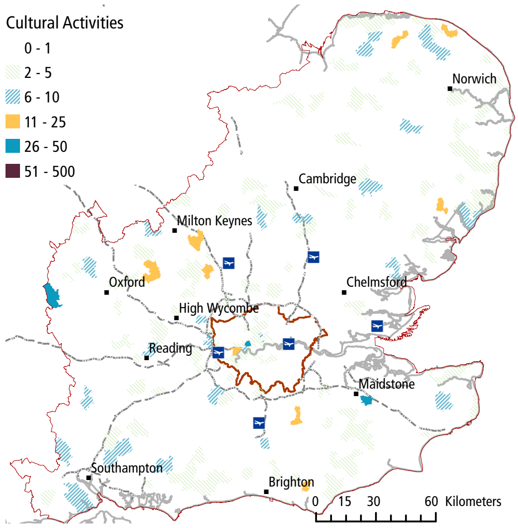
fine-grained structure to London's creative community: people involved in 'Film and Video Production' (Figure 10.12c on page 373) can be found in three parts of London, each seemingly near to a different source of income, and 'Artistic & Literary Creation and Interpretation' (Figure 10.13a on page 374) is concentrated in Central London. What's interesting here is that in terms of employment there is an obvious and absolutely critical role played by the public broadcaster, and that this concentration seems to be having a significant effect on employment in the surrounding PXAs (see page 124 for a discussion of the 'Out of London' strategy).

We can better understand these dynamics by turning to Figures 7.20a and 7.20b which shows the distribution of a broad group that includes the operators of cultural infrastructure such as museums and galleries. Two areas within London stand out as the heart of the largest complex: the BBC's White City development again, and a second grouping near Hounslow that is home to BBC Worldwide. There are are also very high LQs visible in Figure 7.20b near Maidstone; these appear to be related to small and mid-sized production firms, but they are not statistically significant when we drill down to the 4-digit levels in Figures 10.33, 10.34, and 10.35 (see pages 396 through 398).

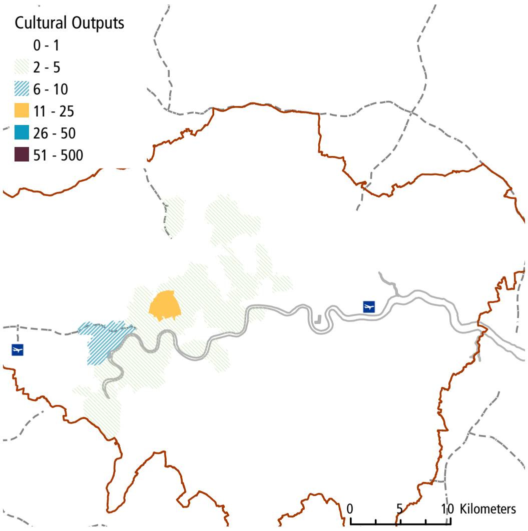
Figures 10.30c and 10.31a (pages 391 and 394) broadly suggest that cultural activity workers as a whole are more widely distributed than the cultural producers group. But Figures 7.20c and 7.20d, which focus on Motion Picture, Radio and Television Production, and the Artistic and Literary sectors, also emphasise that the distribution of activity across Central, Inner, and Outer London is far from random. The broader GSE scale suggests that cultural producers are physically concentrated into a smaller number of 'signifying districts'—there is a particularly concentrated group of statistically-significant PXAs shown in Figure



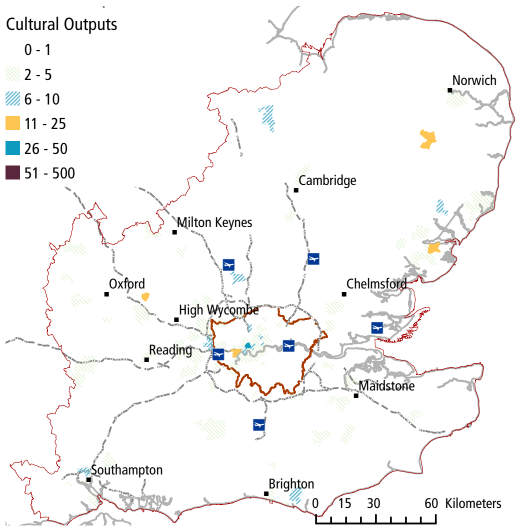
(a) London Cultural Activity



(b) GSE Cultural Activity



(c) London Cultural Production



(d) GSE Cultural Production

Figure 7.20: Cultural LQ Results

10.31b—but we should note that cultural activity and production are far from being confined to the West End and Soho.

In sum, Figure 7.20 suggests that cultural work is not necessarily centralised, but it is highly clustered. In other words, cultural work does *not*, as has sometimes been suggested, happen exclusively in the cores of world cities; instead, it crops up at locations across the region. So although it is the Hollywoods and the West Ends of the world that receive the research attention, these figures emphasise the existence of a network of smaller subcentres that, I suspect, act as feeders of, and highly-specialised suppliers to, the most sophisticated consumers and clients. I am also suggesting that where cultural production *does* happen, it tends to be highly concentrated in space, and that the small number of places that have such employees tend to have rather a lot of them. Because we tend to see the same small areas having statistically significant levels of employment across several SIC codes, this is strongly suggestive of clustering behaviour and, consequently, of informational exchange that does not necessarily happen via telecommunications. In contrast, the areas outside of London tend to be more specialised in just one employment sector, suggesting less direct, face-to-face (F2F) interaction between sectors.

Communication Activity

Using the methodology set out above for selecting 'significant' locations for each knowledge base, we can then consider whether and how these areas differ in terms of their communications activity. The TQ is the simplest way to envision these differences, so Figure 7.21 compares the level of international calling activity for the broader Symbolic and narrower Cultural Producers groups. Recall that the TQ calculation enables us to assess the balance between international calling and all calling activity in the same way that the LQ enables us to do for relative employment concentration. To ensure consistency, we divide each significant PXA's international minutes by *all* inbound and outbound, domestic and international, minutes for the PXA. We then do the same for the region as a whole so that we can see how far the significant locations depart from the regional norm.

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(a) Symbolic

Suppressed from electronic copy at request of research partner

(b) Cultural Production

Figure 7.21: Symbolic TQs & Average Signals

As we would expect, there are more signifying Symbolic PXAs, and they display wider variation, than the Producers' PXAs. In Figure 7.21a, metropolitan London contains three areas with obviously high levels of international calling relative to domestic calling, but areas near Brighton, Oxford, and Milton Keynes are equally global in outlook. In contrast, Figure 7.21b suggests that globally-oriented production activity is more narrowly constrained to Inner and Outer London (Central London PXAs are too diverse to meet the 10% employment threshold) and, with the notable exception of an area near Oxford, the other PXAs all have TQs that are in line with the wider regional norm.

Using these same significant activity areas to perform an eigenplace analysis suggests a more complex relationship between telecommunications usage and Symbolic knowledge work. The input data was the same—in both cases we are using bidirectional domestic and international minutes of talk time to classify the PXAs—but in the eigenplace analysis the timing of the minutes is *also* a factor in the resulting categorisation. Since we are no longer normalising the data against total telecoms usage, I also—as discussed on page 261—adjust the signal processing so that the hourly call volume is normalised by the number of active phones in the area.

The time dimension is captured in both the eigenvectors and in the related Fourier Transform process. We can see in Table 7.6 that the discriminant features have been pulled from the latter set of calculations alone, but that they have come from both the domestic and international calling activity. Since the feature selection process is designed to extract representative features, this implies two possible scenarios: either that the eigenvectors are not particularly useful in finding differences between the significant locations in this particular data set, or that some of the PXAs in this set have particularly unusual patterns of activity which give the Fourier Transform features a broader spread, and thus greater utility to the k-Means clustering.

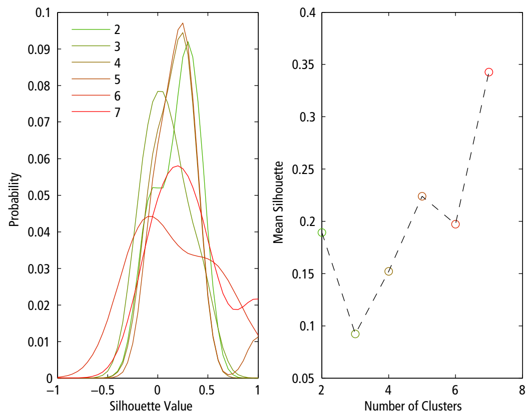
Selected Domestic Features	Selected International Features	Silhouette Test Results
Fourier Transform 1, Fourier Transform 2, Fourier Transform 3, Fourier Transform 6, Fourier Transform 8, Fourier Transform 9, Fourier Transform 15, Fourier Transform 25, Fourier Transform 29	Fourier Transform 1, Fourier Transform 8	

Table 7.6: Symbolic Eigenplace Classification

The silhouette plot in Table 7.6 suggests that 7 clusters are needed to adequately categorise the range of calling behaviours from significantly Symbolic areas. Given that there are just 16 PXAs in the Symbolic group this is quite a striking result since it suggests substantial variation in calling activity. But as we can see in Figure 7.22, the large number of clusters does not mean that the results become spatially meaningless. The representative signals shown in Figure 11.22 (see page 444) can help us to further decipher these findings: Cluster #7 contains Soho and, as such, contains very high levels of international and domestic calling. In fact, these levels of activity are so high that no other area remotely compares, highlighting the unique nature of this neighbourhood.

Furthermore, we can infer from the pattern of international calling that the dominant interaction partner for Soho is North America: note the afternoon uptick in communications on weekdays that is largely absent from other PXA signals. This timing dimension simply cannot be picked up by a TQ analysis at the same level of granularity and it would be necessary to unbundle calling to the country level in order to see any signs of this effect. Note too, that the representative signals from the clusters in Figure 11.22 also enable us to infer that some of the PXAs contain cultural infrastructure for performances: Clusters #2 and #4 (one of whose PXAs is centered on Glyndbourne) have measurable levels of domestic and international calling on the weekends, especially on Saturday and Sunday evenings, that mark them out from both the Soho PXA and from the more modest calling levels in Clusters #1 and #5.

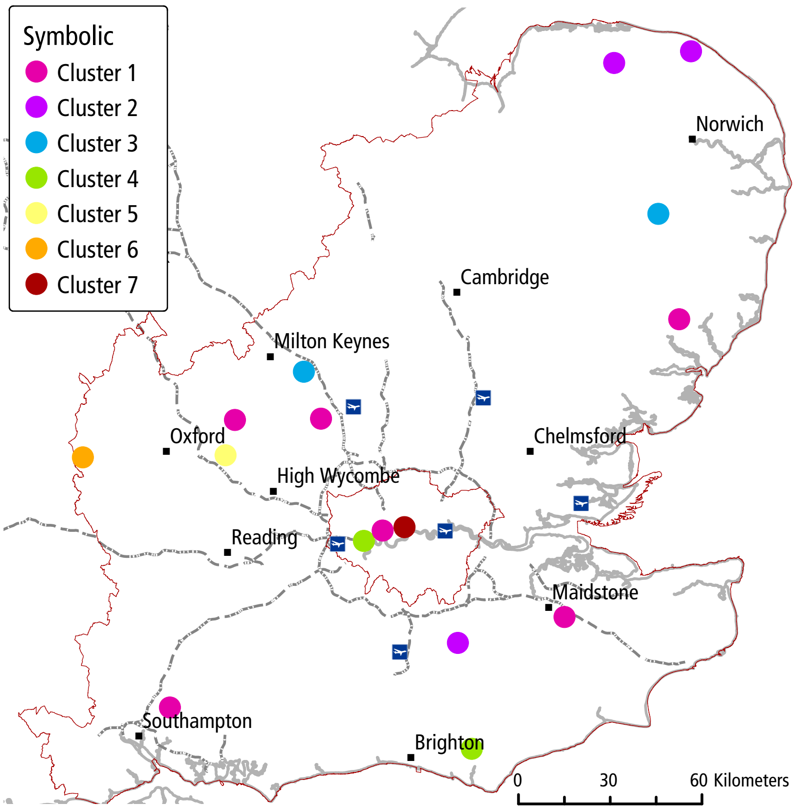


Figure 7.22: Symbolic Eigenplace Results

In contrast to these other categories, Cluster #6 suggests something altogether different: although domestic calling strongly follows the weekly work cycle, international calling is substantially *higher* Friday through Monday. The timing of the data extract (August) and the location of this particular PXA (the Cotswolds) helps to explain why this particular area was classified this way: it encapsulates activity at a tourist destination with a long-weekend dynamic. Cluster #5 also proves to have unique characteristics that cause it to be classified separately: Thame is home to one division of a global advertising conglomerate, explaining why its international calling level is so high during the week, but drops precipitously over the weekend. More tentatively, Cluster #3 has interesting links to predominantly domestic attractions: Woburn is home to Woburn Abbey and its associated Safari Park, while Norfolk hosts Banham Zoo and a range of other, lesser cultural activities.

Summary

In Table 6.2 (page 214) we predicted that Symbolic work would tend to be clustered in high-amenity areas, especially those in the core city or cities of the region, and that some firms would also attach a particular importance to access to clients and suppliers. The result was expected to be a predominantly local pattern of interaction with a strong preference for F2F communication, possibly in a way that undermined the importance of telecommunications. It is, of course, impossible to fully validate the last part of this hypothesis, but the results provide promising evidence in support of the principal ideas advanced in Chapter 5.

The highest-level group—Cultural Activity—showed wide variation in a way that is consistent with wildly divergent interaction and location requirements. The importance of major cultural infrastructure to employment in this sector was amply demonstrated by the concentration found in Central London, but the large number of clusters identified from just 16 significant areas suggested major differences, with a strong spatial flavour, in telecommunications usage. In contrast, the more fine-grained Cultural Producers group demonstrated substantial overlap between sectors within the GLA area, especially around the BBC facilities and in Soho, which I take to be strong evidence of clustering behaviour: sustained interaction across sectors involved in multilateral exchanges.

Beyond London, the degree of inter-sectoral agglomeration appears to decline significantly, even though high LQs appear throughout the GSE region. Proximity to London appears to correlate with the internationalisation of communications activity, suggesting that these secondary, and seemingly specialised, agglomerations vary in terms of their global client base or ownership structure. This overall dynamic, however, is what makes the particular pattern seen in Advertising industry so peculiar: agencies are widely assumed to be the dominant actors of the Soho cultural landscape (see, for instance, Nachum and Keeble, 2003a and Nachum and Keeble, 2003b). Instead, while there is a tendency towards a CBD location, there are major concentrations of employment much further out, with strong evidence of international links near Oxford, Chelmsford, and Luton.

The particularly prominent site in Thame highlights what may be a new locational strategy in the advertising sector: this single-office facility appears to focus employment in some of the non-creative aspects of the industry, suggesting that we may be seeing here the first signs of an emerging front-/back-office dynamic in this sector where MNE firms are concerned. In-depth qualitative research with the large agencies would be required to validate this tentative conclusion, but it would not be inconsistent with the picture that I have painted in the preceding chapters: the increasing power of ICT may be allowing less client-intensive work to be shifted outwards, to less costly locations than those required by the 'creatives' and the account managers.

7.7 *Synthetic Industries*

Spatial Distribution

The Synthetic group is much larger than the equivalent Symbolic and Analytical groupings, so I have divided it in two: the sectors dominated by financial services activities, and those presumed to be organised around the provision of consultancy services. Of course, it could be argued that there are aspects of each group, especially in insurance and financial intermediation, that are more Analytical in nature than they are Synthetic; however, the inability to distinguish between types of activity at a finer scale within each SIC category is a basic limit of the typology and, as we have seen in previous chapters, a good deal of high-end finance is surprisingly 'high touch' and involves close collaboration between financiers, accountants and legal specialists. And even though many of the details of a particular transaction are unique, they are nonetheless part of a relationship expressed through ongoing interaction. Consequently, I have kept the majority of consultancy employment—with the exception of Advertising, which I categorised as Symbolic work—within the Synthetic Industries category in the hopes that this will make clear the locational tendencies.

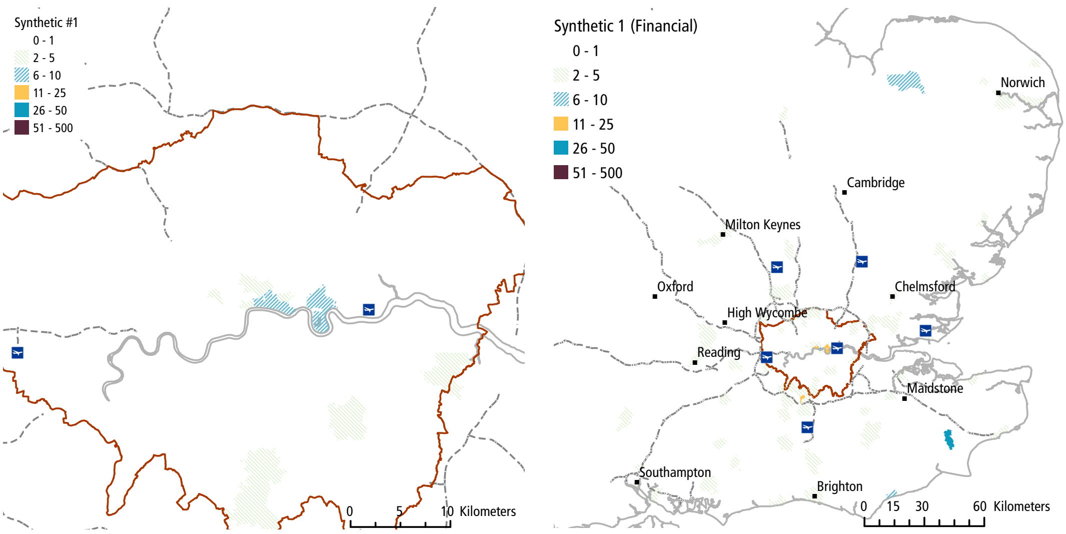
Sector	SIC	Central London	Inner London	Outer London	Outer Metro Area
Central Banking	6511	95.2%	0.0%	0.0%	4.8%
Other Monetary Intermediation	6512	51.9%	12.7%	15.1%	20.2%
Financial Leasing	6521	21.6%	4.8%	14.1%	59.5%
Other Credit	6522	23.5%	5.7%	15.8%	54.9%
Other Financial Intermediation	6523	54.6%	35.2%	3.5%	6.7%
Life Insurance	6601	31.6%	0.5%	10.8%	57.1%
Non-Life Insurance	6603	40.7%	1.3%	21.6%	36.4%
Finance Market Administration	6711	65.5%	5.9%	10.7%	17.9%
Brokering & Fund Management	6712	76.7%	13.6%	1.8%	7.9%
Financial Intermediation Auxiliary	6713	42.0%	23.4%	10.9%	23.7%
Insurance Auxiliary	6720	50.3%	3.1%	14.9%	31.7%
All Sectors		26.0%	11.0%	25.6%	37.4%

Table 7.7: Synthetic Group #1: Finance (adapted from Smith, 2011)

Table 7.7 makes it fairly clear that the dominant tendency for financial services is to have a CBD focus: many of the activities listed show more than 50% of all employees working in Central London. For a regulatory body such as Central Banking it is hardly surprising to see that 95% of staff are based in Central London (the remaining 5% of staff are actually involved in the physical printing of money), but in the case of select industries such as Fund Management, the percentage of employees within Central and Inner London also exceeds 90%! The obvious exception to this 'rule' is the distribution of insurance and leasing activities since these sectors have just 25% of employees in Central London and as much as 60% in the Outer Metro Area.

In the case of Financial Leasing, it seems reasonable to infer that this is a relatively higher-volume and lower-margin 'retail' business. In other words, I assume here that the users of leasing services have little need to coordinate complex interactions and so this would be a good candidate industry for the kind of 'deterritorialisation' that ICT enables. But why is the behaviour of insurance so different from the other types of high-finance? Clearly, some insurance is consumer-oriented and so might be expected to follow the people, but some insurers are engaged in complex, hedging transactions—the failure of AIG highlights the extent to which they are implicated in high finance—but they seem to have been able to shift a good deal more activity outwards to lower-cost areas than the other sectors in this group (see especially Figures 10.37c and 10.37e on page 400).

In spite of this puzzling anomaly (to which we will return later), the overall pattern of activity is strongly suggestive of a front-/back-office distribution: high-level, interaction-intensive activity is focussed in the heart of the CBD, while more technical 'support' functions have shifted outwards to cheaper properties beyond the M25. The natural implication of this distribution is that the insurance sector does not, on the whole, have the same interaction requirements: many insurers will have substantial risk analysis and client/claim management teams that have little need to work with others, but this would be in sharp contrast to the analysts of investment banks or hedge funds who need to meet with lawyers, accountants, clients, and firms in which they hold, or are taking, positions.



(a) London

(b) GSE

Figure 7.23: Synthetic Group #1

Turning again to an LQ-based map enables us to establish whether the distribution follows a particular spatial logic. Figure 7.23a highlights the extent to which Synthetic employment in the financial services sector is highly-concentrated: the City and Canary Wharf dominate, with lesser sub-centres around Bromley, Croydon, and extending Southwards towards Reigate. Expanding this picture to take in the rest of the GSE in Figure 7.23b emphasises the concentration of financial activity in Central London but also throws up several surprises: Tadworth/Coulsdon, Redhill, and Haywards Heath/Burgess Hill are not sites well-known for their financial services; Bexhill and Castle Acre still less so.

A more fine-grained view suggests that very particular dynamics are in operation here. The lognormal version (see Figure 10.28d on 389) highlights PXAs containing statistically-significant levels of activity across a much broader section of the GSE than normally envisioned by the globalisation literature. Is it the case that these are domestic centres, or has the globalisation literature got it wrong? What seems to unite the sectors outside of metropolitan London is that they are all highly-accessible *from* Central London, and especially so by rail: the Gatwick/Brighton line, the Reading line and, to a lesser extent, the Woking/Guildford/Portsmouth line. In addition, there are concentrations of activity around the M25, which would seem symptomatic of facilities not directly engaged in trading or deal-making activity.

Generally speaking, it is the Intermediation activities that seem to attach the most importance to Central London when we look at statistically significant over-representation in PXAs across the GSE. In contrast, Non-Life Insurance and its Auxiliary functions appear to be the most dispersed, while Brokering and Fund employment offer the strongest hints of a front-/back-office division. This pattern is strongly suggestive of the type of locational strategies discussed in the theoretical portion of this thesis: complex support functions adhere to agglomerations of clients with specific interaction requirements, while firms with more standardised communications needs exploit the ubiquity of telecommunications to move outwards from the CBD when the opportunity arises.

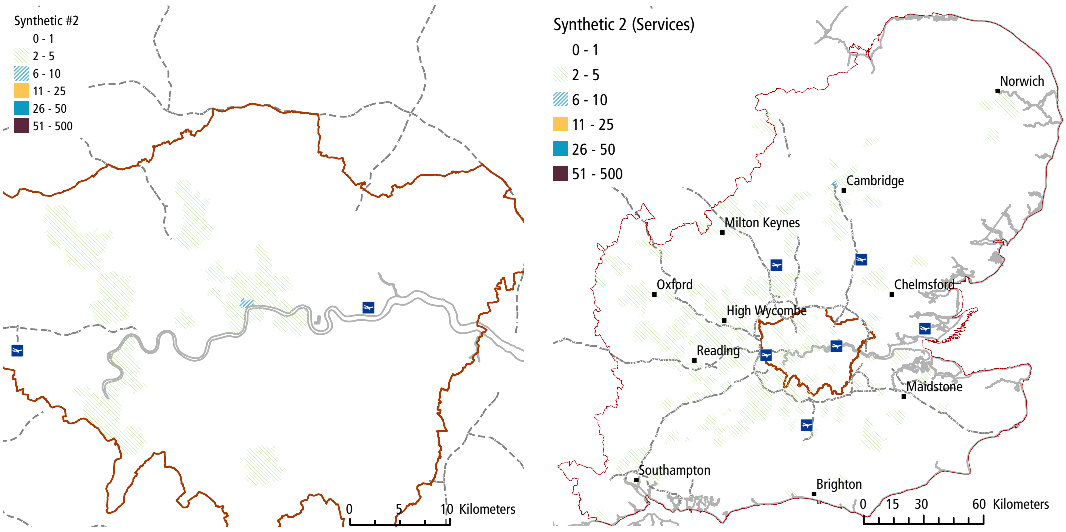
The implication then is that financial services activity tends to be clustered (many firms operate in proximity) but that only some functions are centralised (not all firms cluster in the CBD). What distinguishes the two dynamics is the degree of complexity and specialisation: the more complex and specialised the activity the greater the likelihood that it will be found in Central London. However, in order to verify this conclusion it will be rather helpful to examine the telecommunications flows in greater detail since the NOMIS employment data does not enable us to distinguish between front- and back-office work directly: workers at both ends of the knowledge work spectrum within a financial services firm are all lumped in together under a single SIC code. Nonetheless, even with this static view of the data there is strong evidence here of trade-offs amongst firms operating in the financial services sector between accessibility to Central London and the need to house large numbers of people, not all of whom are directly involved in deal-flow and transactions.

Table 7.8 helps us to further fill in this picture of synthetic knowledge work since it contains sectors strongly associated with consultancy to multi-national enterprises (MNEs). These companies are also expected to have substantial CBD office presences and to be involved in iterative, interaction-intensive transactions with MNEs in finance and

Sector	SIC	Central London	Inner London	Outer London	Outer Metro Area
Legal Activities	7411	64.3%	7.0%	11.9%	16.8%
Accountancy	7412	51.2%	5.0%	15.9%	27.9%
Market Research	7413	38.1%	5.3%	19.7%	37.0%
Business Management Consultancy	7414	38.8%	10.1%	16.5%	34.6%
Management Holding Companies	7415	30.4%	4.2%	16.0%	49.4%
Architecture & Engineering	7420	34.0%	8.4%	16.9%	40.7%
All Sectors		26.0%	11.0%	25.6%	37.4%

Table 7.8: Synthetic Group #2: Support (adapted from Smith, 2011)

ancillary industries. However, they may also be engaged in more 'traditional' forms collaboration—such as product development—with clients either elsewhere in the GSE or, indeed, elsewhere in the world. This dichotomy may help to explain why the distribution of firms in the second group is broadly bimodal, with substantive presences in Central London and in the Outer Metro Area, but comparatively little in between.



(a) London

(b) GSE

Figure 7.24: Synthetic Group #2

Significantly, many of these sectors are the same as those identified by globalisation researchers (see Table 6.1 on page 213), but Table 7.8 indicates that some of these have nearly as many (and in some cases, more) employees in the outermost activity ring as they do in the CBD. Logically, in these cases we are unlikely to be dealing with 'back office' activities of the sort that characterise the retail and support divisions of large financial services and insurance firms since, although these firms may have teams providing ICT and logistical support, they are not providing a transactional service for clients. In fact, the majority of consultants in these industries spend a great deal of time 'on site' with clients and so what we are logically seeing is a distinction between services that require frequent and direction interaction with *other* sectors that are CBD-based, and those that have no such constraints; either because their most important clients are not centralised, or because they have clients across a range of sectors and need to prioritise access to areas other than the CBD.

Within London, Figure 7.24a suggests that these firms congregate heavily near financial services, lending support to the claim that access to the Square Mile is a critical locational feature for some consultancy firms. This would seem to be particularly true of the legal and accountancy sectors that work most closely with firms in the City of London. In view of the London-wide distribution, however, there is a suggestion that access to Westminster may also play a role in locational decisions. At the GSE scale the picture is murkier: only Cambridge has an LQ greater than five and so there is no obvious relationship between this type of synthetic work and the finance sector.

These results would appear to suggest that some firms are serving a wider range of clients regionally, or that they are less specialised than the ones concentrated in Central London (see Figure 10.40 on page 403, and the discussion of Knowledge Intensive Business Services on page 183). To unpick this relationship we can, of course, further unbundle the second Synthetic category into two subgroups: the Legal and Accountancy subgroup (Figures 10.10d and 10.31c on pages 371 and 394) and the Consultancy subgroup (Figures 10.10a and 10.31e). The latter contains sectors such as Market Research, Business and Management Consultancy, Management Activities, and Architectural and Engineering services.

We can see from Figure 10.40a that the Legal sector is extraordinarily tightly-clustered in the City, meaning that we can consider it be highly centralised as well. In contrast, Figure 10.40c (page 403) shows that Accountancy is agglomerated, in as much as there are a small number of statistically significant areas with very high LQs, but shows evidence of dispersal, possibly because it regularly serves clients in a much wider range of industries. The APS group as a whole (Figure 10.30a on page 391), and Business Management Consultancy in particular (see Figure 10.40d on page 403), shows some evidence of concentrations to the South and West of metropolitan London, but the absence of significant centres seem striking—there is, in other words, nowhere that consultants congregate at levels far above the regional norm. Finally, Architecture and Engineering (Figure 10.20a on page 381) appears fairly decentralised, especially when we consider its dispersion around the GSE. That said, proximity to motorways and the existence of a small, concentrated employment area to the West of Central London suggest that access to clients is a locational factor.

Communication Activity

When we select only those locations that have have significant levels of employment (*i.e.* more than 1.5 standard deviations above the mean for lognormally-distributed LQs and more than 10% employment) a pattern of global communications emerges: proximity to London is clearly a strong predictor of an increase international calling activity.

In the case of Synthetic Group #1, the congregation of multinational financial services firms in the City is obvious, but additional research was required to uncover the fact that the southern edge of the M25 is home to the marketing, customer services, ICT and administrative divisions (*i. e.* back offices) of several American financial services firms. Tonbridge, Royal Tunbridge Wells, and Cranbourne/Ascot also display quite high levels of international calling activity relative to the GSE as a whole, but the sites dotting the South coast and East Anglia are clearly much more domestic in their telecoms usage. What Figure 7.25a draws out is the existence of one or two 'corridors' of activity running South into Kent. The existence of these has not, to my knowledge, been broached in the existing literature and their exact function is unknown.

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(a) Synthetic Group # 1

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(b) Synthetic Group # 2

Figure 7.25: Synthetic TQs & Average Signals

Figure 7.25b emphasises the extent to which Synthetic Group #2 is concentrated in just a few areas. Fewer, in fact, than finance! And, whereas areas with significant levels of financial services employment exhibited a range of calling behaviours, with this group there is a clear dichotomy between firms operating in highly-globalised environments in Central London and around the M25, and those operating in second- or third-tier cities and towns elsewhere in the GSE. In the latter case, levels of international calling are only slightly higher than the regional norm which, given their location, also suggests that they are more domestically-oriented.

Nonetheless, we should also note that there is a clear suggestion of three distinct agglomerations here, and that there is a concentration of professional services activity in the vicinity of Cambridge where no less than four PXAs have statistically significant levels of employment in these industries. It will be interesting to see in the subsequent sections whether these marginally less internationalised firms have correspondingly different patterns of interaction, or if this is simply a good base from which to serve clients in the East of England and parts North.

Turning to the eigenplace results, it is sensible to start with the obvious in Figure 7.26: Cluster #3 captures the importance of the City, and it shows not only the impact of post-2 p.m. calling as the American financial markets open, but also the extent to which such calling does *not* occur on weekends. It may well be that traders and other financial workers engage in continued activity over the weekend from mobile platforms and from home, but they manifestly do not do so from the office. Similarly, Clusters #2 and #4 highlight areas near to London known to have significant back office employment—Croydon, Bromley, Reigate, Kingswood, and Royal Tunbridge Wells—as well as the more remote activities of firms in the insurance sector in Peterborough and Norwich. Note too that the average signal in both clusters (see Figure 11.24 on page 447) also contains a small, but significant increase in international communication late in the day.

In contrast to these, Figure 11.24 indicates that Cluster #1 has much lower volumes of both domestic and international calling. So where Cluster #2 appears to contain financial services subcentres with strong domestic and non-domestic links, the PXAs in this other group tend to be much less connected in general. The remaining clusters, numbers #5--#7, show strong variation in calling activity, and only one of the remaining groups contains more than a single PXA, so these area areas with quite distinctive patterns of usage. The sustained levels of activity over the weekend in Clusters #5 and #7 are strongly suggestive of support activities. Cluster #6 has much more in common with Cluster #2, save for the fact that international calling activity accelerates late in the day instead of declining.

We should note too here that the feature selection process documented in Table 11.4 suggests two things: first, that the waveforms are more strongly differentiated than they were in the Symbolic analysis since the low-numbered eigenvectors form an important part of the selection process; second, that we were forced to select a large number of

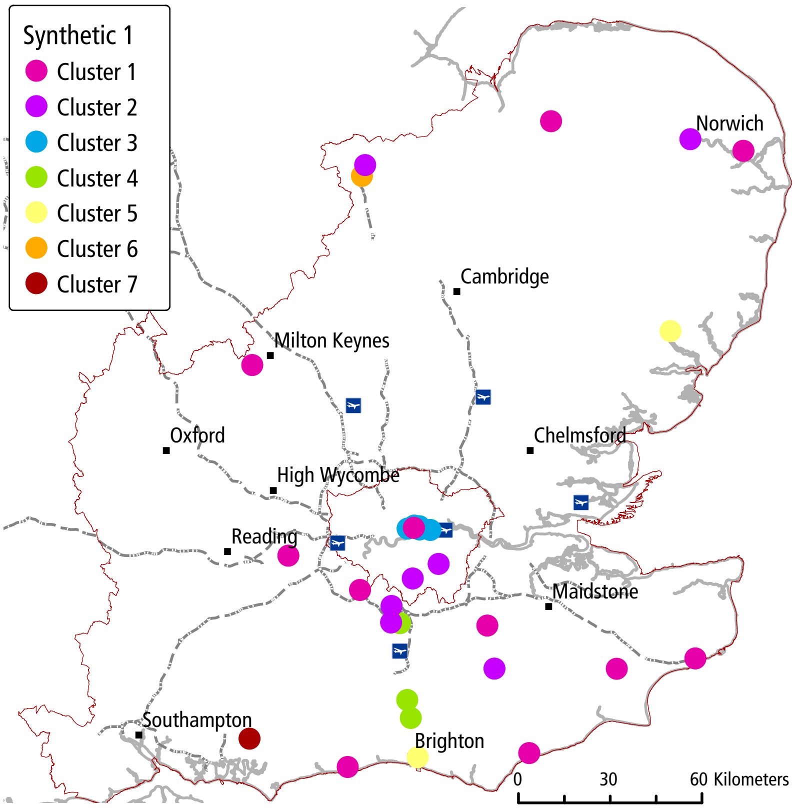


Figure 7.26: Synthetic Group #1 Eigenplace Results

features in order to select more than a single feature. What this means in terms of differences in activity is that the Synthetic group's telecoms usage is, on the whole, more difficult to tell apart but that, once we establish a high enough threshold for similarity, then the differences are more extensive.

As might be expected, the distribution of activity in Synthetic Group #2 shows a pattern that is related to that of the financial services sector upon which so many firms in this group depend, but it nonetheless differs in significant and interesting ways. The silhouette plot (page 449) indicates a fair result from the eigenplace process, and Clusters #1, #2 and #5 all demonstrate the markers of internationally-oriented communication, especially with America. For Clusters #2 and #5 this behaviour is to be expected since the PXAs are located in Central London and are adjacent to the major centres of global financial activity. Interestingly, Cluster #1 shares these characteristics, including locations elsewhere in London—the centre-most of which has massive levels of international calling—and near Reigate, but there is also evidence here of firms with little connection to the finance industry located on the M11 near Cambridge.

Clusters #3 and #4 both contain PXAs with rather less in the way of international interaction—they differ in the extent to which domestic telecommunications are employed—and so it is reasonable to conclude that the firms in these areas may be rather less global. Altogether different, however, are the activities in Clusters #6 and #7. Both of these PXAs have modest international activity but are easily distinguished

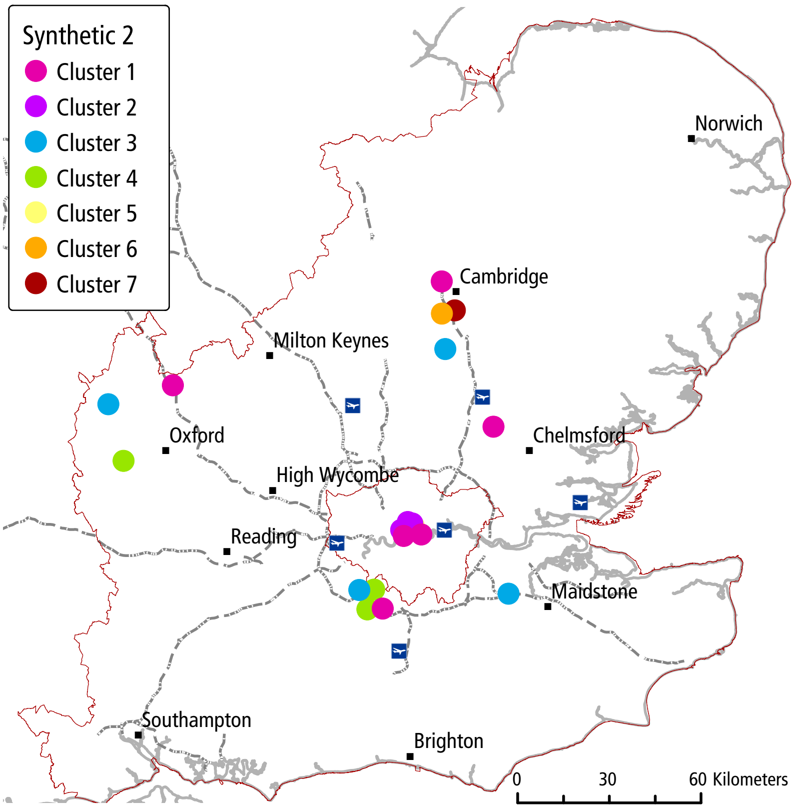


Figure 7.27: Synthetic Group #2 Eigenplace Results

from the other PXAs by virtue of their domestic activity: Cluster #6 shows a surge in call volumes between midnight and 6 a.m. while Cluster #7 shows significant levels of *per phone* level calling throughout the night. Neither of these behaviours is, strictly speaking, intelligible if we assume that people are responsible; however, the timing of the communications suggests that some of these calls may well be automated exchanges of information or that there are firms in this area to the South of Cambridge that have unique interaction requirements.

Summary

Combining the LQ, TQ, and eigenplace analyses yields several important conclusions, the first of which is that the City of London remains the absolutely critical site for financial activity in the GSE. There is strong, direct evidence of clustering here: not only is the City a statistically significant site for one sector, it is often the most significant site in the entire sample for *many* specialties within the financial services sector. This is particularly important evidence of multilateral exchanges having been a driving force of agglomeration in this tiny portion of metropolitan London, but it does not address the question of whether this physical proximity remains important today.

Further out from London there is much less geographical overlap between the activities associated with this group, suggesting greater specialisation and less F2F interaction. The lack of direct interaction may, however, be matched by a higher rate of mediated interaction. Although every PXA associated with the financial sector uses international and domestic communications channels, the biggest users of domestic telecoms are nearly all outside of London. In Table 6.2, I proposed that financial firms would be predominantly global or very local in their telecoms usage, but what these findings suggest is the existence of a wide-ranging regional ecology that involves extensive domestic communications as well.

Where the global financial services industry shows strong evidence of clustering behaviour, the same is not true of the second Synthetic group explored in this section. Here, concentration near the centre of London and around the M25 seems to be driven by access considerations, with little evidence across the majority of industries of a need to interact closely with other sectors. There is also a strong demonstration of the KIBSdisposition considered earlier (see page 183); specifically, centrally-located KIBS-dominated areas have far more intensive international communications than do PXAs further out from the CBD. The general locational and communication pattern would be consistent with a distinction between firms which operate in highly competitive, global environments around the CBD and those which operate across the regional 'periphery'. Elsewhere in Britain the periphery might be a weak source of revenue, but the scale of employment across the GSE makes this a lucrative proposition.

Intriguingly, we found that the Legal industry is the most highly concentrated sector in the entire sample. The sector is tightly clustered in the very centre of London's core, suggesting that this agglomeration is the most highly specialised service-provider of all. In contrast, Accounting offered evidence of significant agglomeration near each of the GSE's largest cities (and a particularly high concentration near Southampton), and this may reflect the office structure of the sector's near-oligopolies since just four firms are able to provide accounting services on a truly global scale. Finally, Architecture, Engineering and, more surprisingly, Management Consulting showed strong evidence of regional dispersal: the first two in particular indicate a lack of a agglomeration across the sector but, rather, large offices having relatively little to do with one another.

7.8 Analytical Industries

The final group of intensive knowledge workers—the Analytical group—is principally composed of scientific and computing firms. As such, this group is markedly different from the other knowledge bases studied. Firms operating in these sectors are generally presumed to have much more modest interaction requirements thanks to the power of codification, and many of their outputs are easily transmitted either physically or electronically around the world. In the Methodology, I suggested that, based on the picture assembled over the previous four chapters, firms involved in 'high-tech' work would tend to prefer sites that have traditional types of amenity, especially the residential ones such as good schools, large properties, and access to nature. We also anticipated that, as a result, such firms would of necessity be amongst the most global in their communications profiles.

Spatial Distribution

An examination of Table 7.9 quickly reveals a markedly different distribution of employment from the Symbolic and Synthetic firms considered above. Here, in stark contrast to the Symbolic workers considered on page 277, there are just two groups with much more than 25% employment in Central London, and none have employment levels of note within Inner London. Instead, Analytical workers are far more abundant in the OMA region: nearly all SIC groups have more than 50% of staff concentrated in the outer-most ring.

On the surface of things, we might initially conclude that this distribution is—much as it was for the Synthetic workers examined on page 284—indicative of front-/back-office relationships. However, the tiny amount of employment in Central and Inner London, together with the strong tilt towards the OMA region actually suggests that a very different dynamic is at work. There are two altogether different possibilities: either many firms have no presence at all in Central London and there are only a small number of specialised suppliers to be found there, or the largest firms have small sales outposts in the CBD so that they can meet with clients and close deals but the bulk of the 'real' work is done far from London.

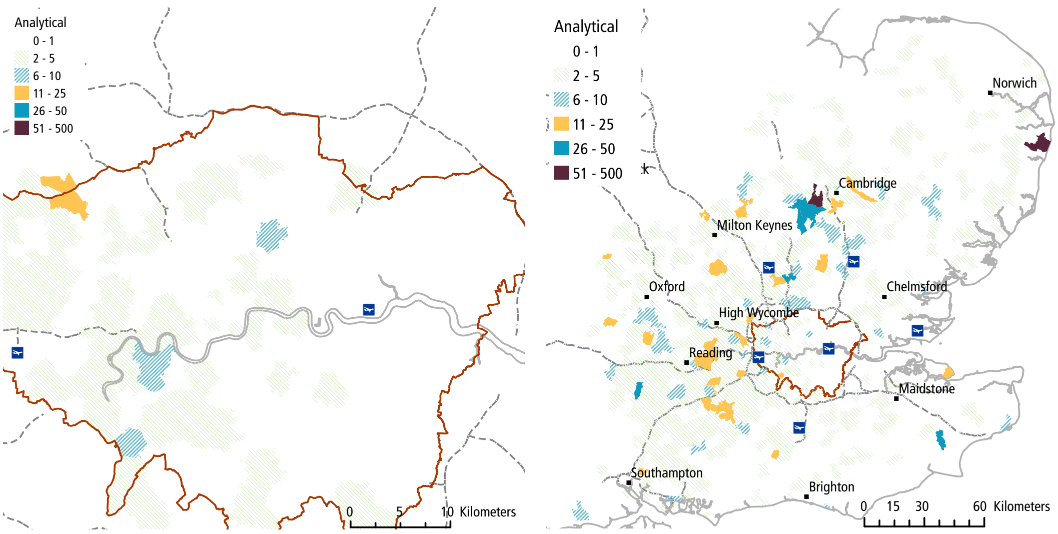
Sector	SIC	Central London	Inner London	Outer London	Outer Metro Area
Hardware Consultancy	7210	11.9%	10.0%	17.0%	61.1%
Software Publishing	7221	14.2%	6.7%	24.0%	55.2%
Other Software Consultancy	7222	24.3%	6.0%	17.6%	52.1%
Data Processing	7230	23.1%	4.8%	21.9%	50.2%
Database Activities	7240	43.3%	4.3%	16.7%	35.7%
IT Maintenance	7250	12.8%	3.2%	24.7%	59.4%
Other Computer	7260	25.6%	8.4%	20.6%	45.5%
R&D (Natural Sciences)	7310	14.7%	6.0%	13.7%	65.6%
Defence Activities†	7522	44.6%	0.7%	12.9%	41.8%
All Sectors		26.0%	11.0%	25.6%	37.4%

† This sector not included in maps or analysis.

Table 7.9: Analytical Knowledge Base (adapted from Smith, 2011)

The two most notable exceptions to the general distribution of activity in Table 7.9 help us to understand in more detail what is happening: in terms of their allocation of employment, Database and Defence Activities (SICs 7240 and 7522) look much more like the Synthetic firms studied in the preceding section than they do like the software and hardware firms contained in this table, while the Software Consultancy sector falls somewhere in between. Firms in these sectors may often operate more like consultancies than they do like producers of a standardised good and, consequently, require much more iterative interaction. In the case of defence there is also, of course, the requirement to be close to government, but there is no sense in which the production and distribution of military hardware is a standardised process.

Similarly, the increasing reliance of all sorts of firms on the processing and management of data—from sales and customer information, to transactional and exchange systems—has created the need for a cadre of professionals who design and implement customised storage and analysis capabilities for clients. From personal experience, I can vouch for the fact that database mining is a 'high-touch' profession involving a great deal of F2F interaction with staff drawn from across a firm's management and divisional structure. As such, this sector is more truly a form of consultancy entailing both a dedicated back office of specialists who deal with technical processes, and a substantial front-office to meet with clients to draw up requirements and deliver reports and analyses.



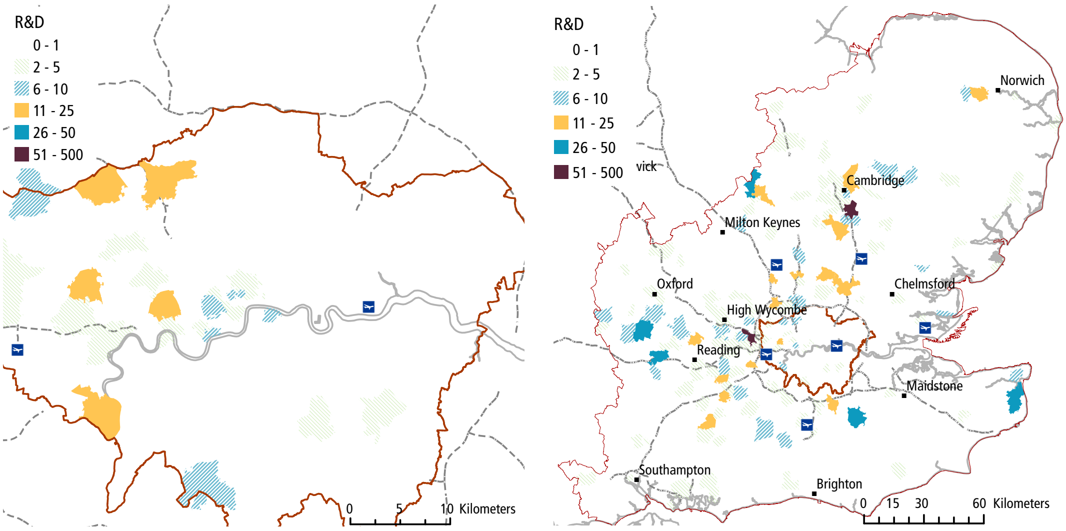
(a) London (b) GSE

Figure 7.28: Analytical LQ Results

At the highest level of analysis, this group is most noticeable in London by where it is *not*: Figure 7.28a shows that there are modest levels of activity across much of the western half Greater London, but very little to the East. The highest concentration of Analytical activity is actually on the very edge of London itself, close to the M25, with slightly lower-intensity subcentres near Richmond, Kingston-upon-Thames and, more intriguingly, in Harringay. Only the Software Consultancy group seems to have a significant central component. It is, however, at the GSE scale that the true magnitude of the difference in locational strategies between this and other knowledge bases becomes evident: high concentrations of Analytical activity occur near Cambridge, Reading, and Guildford, while lesser levels of employment concentration crop up near Ashford, Faversham, and Wrentham.

Narrowing the focus to R&D in the natural sciences[12] in Figure 7.29b brings forward the existence of a pronounced Westward tilt with a second major concentration near Cambridge. Note, however, that both the general and the significant distributions suggest proximity to the major radial routes connecting with the M25, though not to the ones

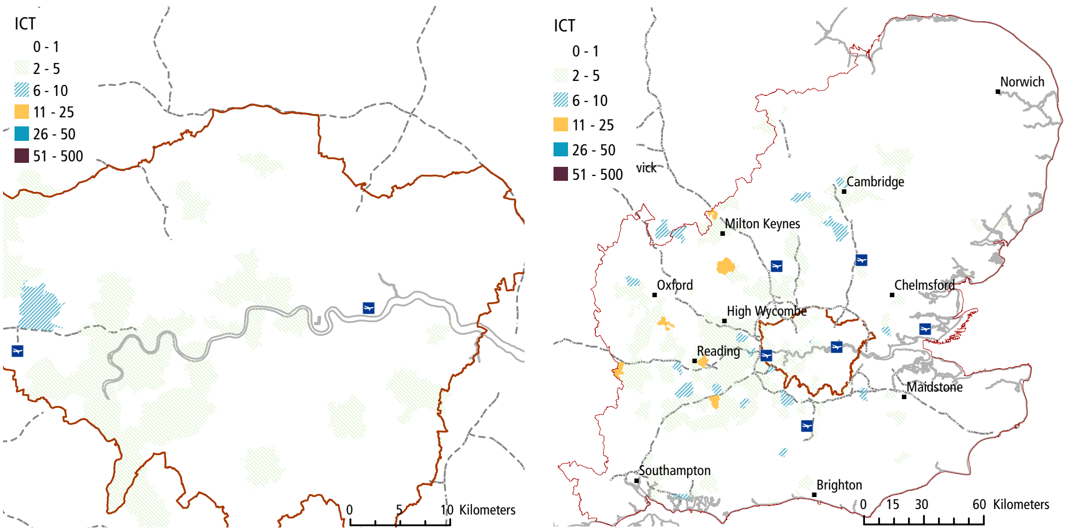
[12] Social science R&D has been excluded on the basis that most of this will be university employment.



(a) London (b) GSE

Figure 7.29: R&D LQ Results

used by financial services. This distribution would, broadly speaking, fit with the expectation we have that R&D activity tends to occur at accessible, but not central locations since the need for F2F interaction is lower, so there is less need to pay CBD-level rents. Interestingly, there is also a seeming *lack* of statistically significant R&D activity in the area between Oxford and Milton Keynes, and even the normal measures suggest quite low concentrations in comparison with the areas due West and North.



(a) London (b) GSE

Figure 7.30: ICT LQ Results

Turning to ICT employment, although overall levels of concentration are lower, the spatial distribution is more marked: the 'Western Wedge' posited by Hall (1987) is particularly evident in an arc that is centered on Reading, but which swings from the M3 in the South to the M40 in the North (see Figure 7.30b, and also Figure 10.32b on page 395). These dynamics are highlighted in the map of significant PXAs on page 387, which suggests that ICT location is characterised by proximity to motorways and to airports in a way that R&D activity is not.

Some of the highest concentrations of R&D activity occur in relatively less accessible areas such as Sandwich, Royal Tunbridge Wells, and Sharnbrook, whereas even the Software Publishing sector (SIC 7221), which should have relatively little in the way of external dependencies, is still located close to major motorways and within striking distance of an airport. For Other Software Consultancy (SIC 7222), there are a high number of significant locations to the West/Southwest, but equally interesting are the areas that have significantly *lower* levels of activity: the GLA region has many areas where the distribution is more than 1.5 standard deviations *below* what we'd expect given the regional norm!

Communication Activity

The TQ maps in Figure 7.31 provide additional perspective on the distribution of Analytical workers. Figure 7.31a highlights two particularly important dynamics: first, that there is a *lot* of analytical activity taking place to the West of Greater London, and that quite a bit of it is operating in a very international context; second, that there is a visibly important secondary cluster of analytical activities in the vicinity of Cambridge. Comparison of Figures 7.31a and 7.30b makes it clear that some of this dynamic originates with the ICT industry, but note that industrial concentration is not, in and of itself, a sufficient cause of the level of international calling levels seen in the TQ map (compare the degree of internationalisation in Figure 7.31a with the levels of statistically significant concentration seen in Figure 10.32b on page 395).

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(a) Analytical

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(b) R&D

Figure 7.31: Analytical TQs

Most obvious in Figure 7.31b is the extraordinarily high level of relative international activity in Sandwich, home (until recently) to a major pharmaceutical research centre. More subtly, we should note that the majority of statistically significant R&D sites seem quite far removed from Central London when compared with the other two knowledge bases, and that distance from London also seems to have little impact on their use of international communications. This seems to fit with the predictions developed over the course of the previous chapters, except that the levels are often lower than we anticipated—the firms *are* using telecoms to communicate internationally, but the codifiability may be being expressed through a reduction in voice communications/coordination and an increase in Internet-enabled interaction that is largely invisible.

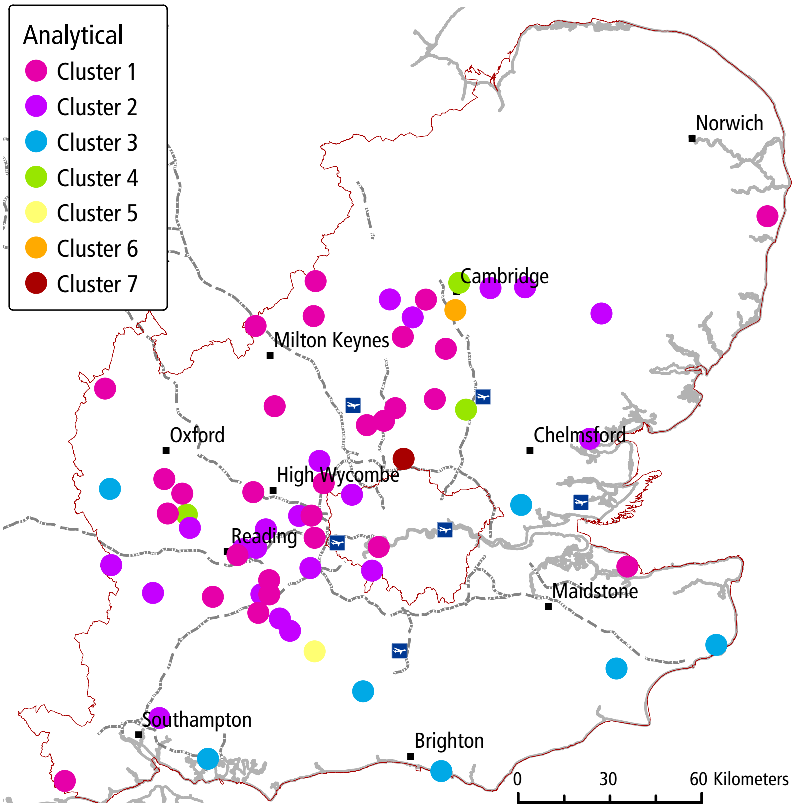


Figure 7.32: Analytical Group Eigenplace Results

The first thing to notice about the results from the eigenplace analysis is that that the representative signals (see Figure 11.28 on page 451) indicate that there is, on the whole, less interaction in the PXAs where analytical firms locate, and that none of them approach the massive *per phone* volumes seen in the Synthetic groups. Clusters #1, #2 and #3 differ principally in the extent to which they use telecommunications at all: the averages for domestic volumes are only just distinguishable to the eye, and only Cluster #2 shows modestly higher rates of calling across the board and a noticeable afternoon skew in international volumes.

This pattern is, however, nothing compared to what we see for Cluster #4 where the levels of international calling can *exceed* domestic volumes for much of the afternoon. This surge has no counterpart in any other group, and so it is strongly suggestive of a uniquely Analytical behaviour linked to communications with America in general, and the West Coast in particular. As before, Clusters #5, #6, and #7 contain just a single PXA, signalling that their patterns of usage are very different from the much larger Clusters #1 and #2. In particular, Cluster #6 shows the same, puzzling pattern seen in the Synthetic analysis, while Cluster #7's massive usage levels show why the patterns observed for the Synthetic group were less pronounced.

The fact that we have the same PXA acting as a significant area for both the Analytical and Synthetic groups points to one limitation of this approach: although I have required that at least 10% of employment in a PXA be from the sector of interest, that could still leave 80% of employees uncounted. In other words, the distinctiveness of the interactions found here could indicate the influence of a *third* large sector in the vicinity. If that is the case, then the aggregate results could be misleading if we were to attach too much importance to them in isolation. However, the flip side of this very same issue is that without the interaction data we would have no idea that such a situation even existed and warranted further investigation.

Summary

The findings from the LQ, TQ, and eigenplaces analyses highlight the Westward tendency of this group, and it seems significant that the majority of sites with lower levels of telecommunications activity—and especially international telecoms activity—are to the East and South. One of the eigenplace clusters, Cluster #4, seems to have captured what appear to be critical anchor points in the globalisation of this type of activity: their usage of international calling suggests significant informational flows from abroad and, most importantly, from America. The high number of statistically significant sites suggests large facilities such as offices and office parks, but little in the way of spatial overlap between the individual sectors. Unlike the conjunction of activities seen in some of the Synthetic and Symbolic sectors, Analytical firms largely appear to physical prefer separation.

Moreover, the communications results suggest that if interaction is occurring between the offices of Analytical firms then it is not taking place via voice calls in this data set. Given that the data is taken from 2005, this data set may post-date the transition from traditional voice calling to application-based VOIP products such as Skype. As well, the formal constraints of programming languages mean that it is much easier to share work across national and even, though to a more limited degree, linguistic boundaries. Modern coding environments (*e.g.* Integrated Development Environments) and distributed version control systems mean that physically remote groups can each work on a different part of the entire system or application but synchronise their output at the end of the workday automatically, without the need to actually discuss the day-to-day workstream.

There are indications that *some* ICT employment occurs in close proximity to the CBD, and I wonder if (as discussed earlier) this is a manifestation of the distinction between software as a product (decentralised) and software as a service or project output (centralised). Unfortunately, the NOMIS and census data are not sufficiently detailed to support this type of examination but, in general, despite taking less central locations, Analytical firms are still most often found in sites that are accessible—especially to private vehicles—and so they are only peripheral relative to the CBD, but not to employee housing or to airports. In fact, ICT betrays the stronger bias towards global access via airports, and the particularly strong use of telecommunications at a few sites is suggestive of high levels of globalisation amongst *some* firms.

The R&D sector shows much wider dispersal across the GSE—some of it clearly connected to pre-existing research centres in places such as Cambridge, but some of it with little obvious connection to anything at all (*e.g.* Sandwidch). International R&D also appears to be a much larger user of global telecoms, and this is perhaps the only sector for which distance from the CBD is no predictor of overall internationalisation of communications. In fact, the majority of external links here seem to be uniquely global—most likely to the other offices of the same firm—and there is little regional or local interaction. Indeed, it was the overall lack of communication that was surprising here: I had expected these firms to make stronger use of telecoms than their counterparts in every sector except global finance, but instead they make comparatively little use of voice calling. Perhaps this is, as I have suggested above, a sign of things to come and a marker of a shift to other interaction channels?

7.9 Material & Immaterial Flow Industries

Finally, because I have drawn such a strong distinction in this thesis between knowledge work and the locational preferences of firms involved in material and immaterial flows of a standardised, ubiquitous nature, I felt that it would be helpful to examine these sectors separately. Broadly speaking, the firms in this section fall into one of two categories: distribution (broadly understood to be either physical or electronic) and production (of physical goods alone).

Spatial Distribution

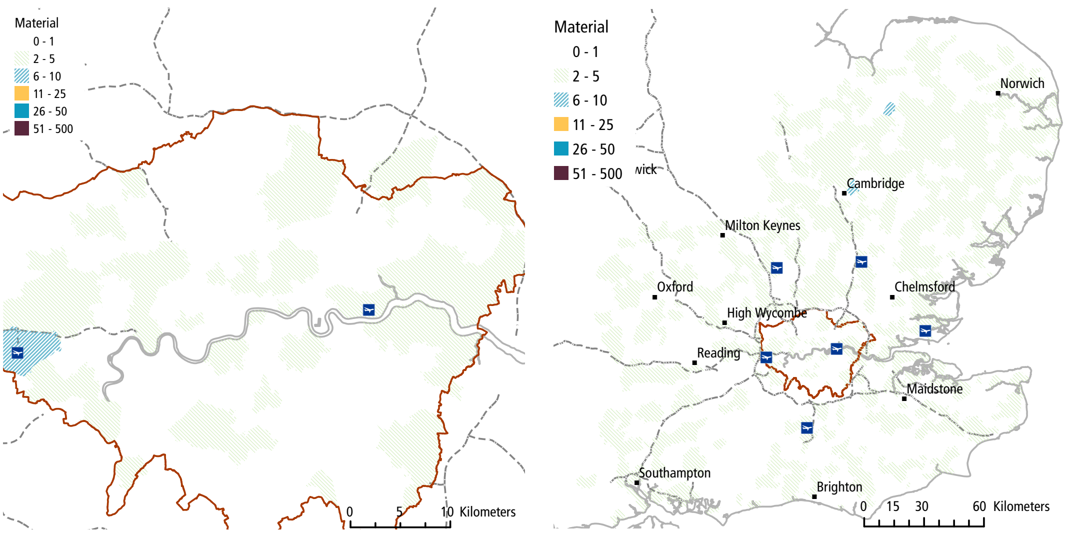
It is immediately obvious from Table 7.10 that we are dealing with an utterly different spatial structure. Although the Analytical group discussed above has significant OMA employment, the figures do not approach the levels seen here. Many of the distributions are to be expected: with the exception of the much smaller City Airport, London's major airports are all in the Outer London or OMA regions and so air transport-related employment naturally follows this distribution. The 2.4% of centrally-located Scheduled Air Transport workers are likely to be the employees of the Civil Aviation Authority (CAA), which is based in Holborn, but the location of the remaining 96.7% make it abundantly clear where the 'work' is done. The parallel distribution of Packaging and Warehousing activities is also notable here, though it too is not unexpected.

However, some of the more unusual distributions require some explanation. The high proportion of Other Land Transport and Other Water Transport in Central London are connected to the provision

Sector	SIC	Central London	Inner London	Outer London	Outer Metro Area
Call Centre Activities	7486	26.8%	3.7%	26.5%	42.9%
Telecommunications	6420	33.5%	5.5%	18.5%	42.5%
Packaging Activities	7482	3.4%	4.4%	29.9%	62.3%
Pharmaceutical Manufacture	2442	1.3%	1.6%	14.5%	82.5%
Computer Manufacture	3002	5.9%	7.5%	41.6%	45.0%
Scheduled Air Transport	6210	2.4%	0.9%	73.0%	23.7%
Non-Scheduled Air Transport	6220	3.8%	1.7%	18.9%	75.6%
Cargo Handling	6311	1.8%	0.2%	46.7%	51.3%
Storage Warehousing	6312	4.3%	4.0%	29.7%	62.0%
Other Land Transport	6321	54.8%	9.9%	19.3%	16.0%
Other Water Transport	6322	20.6%	3.4%	19.4%	56.5%
Other Air Transport	6323	0.9%	0.2%	57.1%	41.8%
All Sectors		26.0%	11.0%	25.6%	37.4%

Table 7.10: Material & Immaterial Flow Sectors by Region (adapted from Smith, 2011)

of London's massive public transit system: in addition to its operation centres, the majority of Transport for London's (TfL) employees can be considered to be working 'from' London, and the water-based group is undoubtedly connected to the tourist boats that ply the Thames between Greenwich and Westminster. The abundance of Telecommunications staff in Central London is related to head office activity—marketing, finance, and management—of the major network operators (*e.g.* Orange, BT), but the presence of 26.8% of Call Centre Activities employees is entirely unforeseen.



(a) London

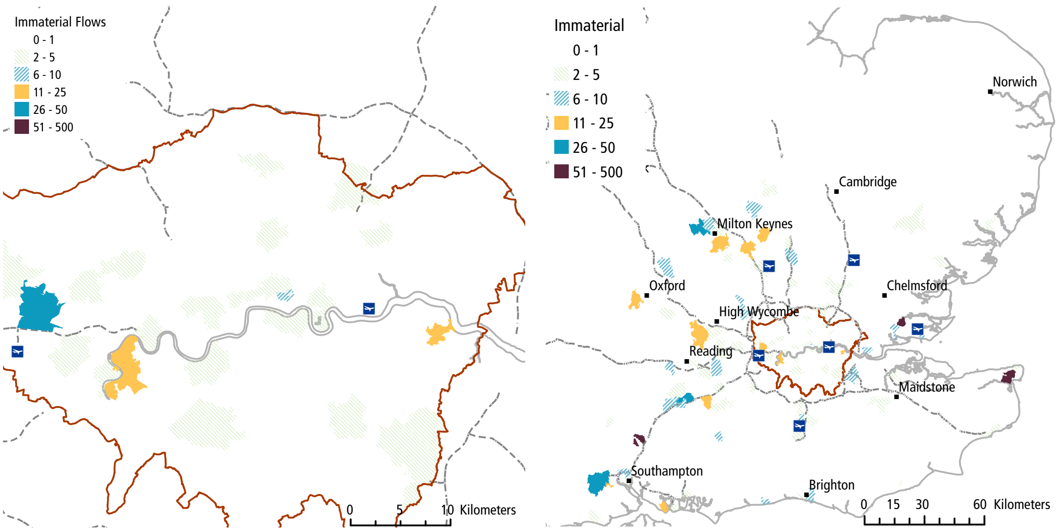
(b) GSE

Figure 7.33: Material Flows LQ Results

Figure 7.33 demonstrates the basic validity of the analysis above: the only notable concentration of Material Flow employment within London occurs at Heathrow Airport (Figure 7.33a), while at the GSE scale even this concentration is 'ironed out' such that employment in the creation and distribution of physical goods occurs nearly everywhere.

In fact, it is only by identifying areas of significant total employment that any kind of general locational pattern becomes evident (see Figure 10.26e on page 387): airports (*e.g.* Luton, Stansted, and Heathrow) and ports (*e.g.* Southampton, Harwich, and Tilbury) are obviously major employers, but the majority of significant locations are in East Anglia between Cambridge and Norwich. We will return to these later, but it is worth noting here that that is also a good deal of rail infrastructure in the area that is not visible in Figure 7.33b.

For Immaterial Flows, the concentrations within London are made more intelligible by projection in Figure 7.34a: a high concentration of workers in Hayes, and lesser centres in Richmond, Erith and, lower still, near Bethnal Green. With the notable exception of Richmond, what seems to unite these areas is the combination of relatively higher levels of deprivation (often characterised by the dominance of immigrant groups) and cheaper land. In that sense, it would seem that data processing and call centre activity has replaced manufacturing within metropolitan London as a source of employment opportunity for more recent arrivals and less skilled workers. At the GSE scale, the cluster of PXAs with high LQs in the vicinity of Milton Keynes represents the first time that we have seen *any* major concentration of knowledge base employment in that portion of the region.



(a) London (b) GSE

Figure 7.34: Immaterial Flows LQ Results

Aside from the Thames Estuary's ports, some of the most visible centres of Logistics activity (see Figure 10.32e on page 395) fall to the Southwest of Norwich (roughly: Thetford, Downham Market, Diss, and Attleborough), but it may be more of a surprise to see concentrations of manufacturing close to Cambridge as well. We can see here again the limitations of the NOMIS data: the manufacturing near Cambridge *appears* to have a strong 'high-tech' component, while Thetford seems to have a high proportion of precision-engineering output[13]. It is therefore possible that certain types of particularly complex or in-

[13] So in Cambridge outputs include fibre optics, research equipment, automation systems, and the like, while Thetford seems tilted towards plastics and types of machining.

novative manufacturing are tightly coupled to R&D employment and that, while they may be more remote from the source of innovation, accessibility to knowledge-producing sites may be a requirement.

Communication Activity

Figure 7.35 enables us to contrast the distribution of international calling by knowledge-intensive activities with that of two sectors that are widely believed to be much less so. The Material Flows group in Figure 7.35a indicates, not surprisingly, that higher levels of international calling are associated with proximity to major entry/exit points for goods (*i. e.* ports, airports) and, to a much lesser extent, with production. Note, however, that the internationalisation of 'high-tech' manufacturing in the vicinity of Cambridge contrasts visibly with the level of international calling across the rest of East Anglia, and note too the level of activity to the West and Southwest of Heathrow Airport.

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(a) Material Flows

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(b) Immaterial Flows

Figure 7.35: Flow TQs

The small number of significant sites for Immaterial Flows in Figure 7.35b makes it difficult to draw meaningful conclusions about this group. The only thing that can be said with any certainty is that concentrations of this type of employment seem unrelated to international calling activity in the area. The lack of internationalisation in what is widely believed to be a highly globalised industry suggests two possible, and potentially complementary, interpretations: the first is that the scale at which this analysis has been undertaken is insufficient to capture the areas (*e.g.* Glasgow, Leeds) where international calling activity might be more significant; the second is that these operations might have relatively little need to interact globally since they exist solely to process informational inputs and outputs connected with the operations of the GSE economy. Since there are just four significant Immaterial Flows sites there was little value to be had in clustering them according to usage.

The large number of features produced by the eigenplace process indicates some difficulty in reducing them to just a few characteristic

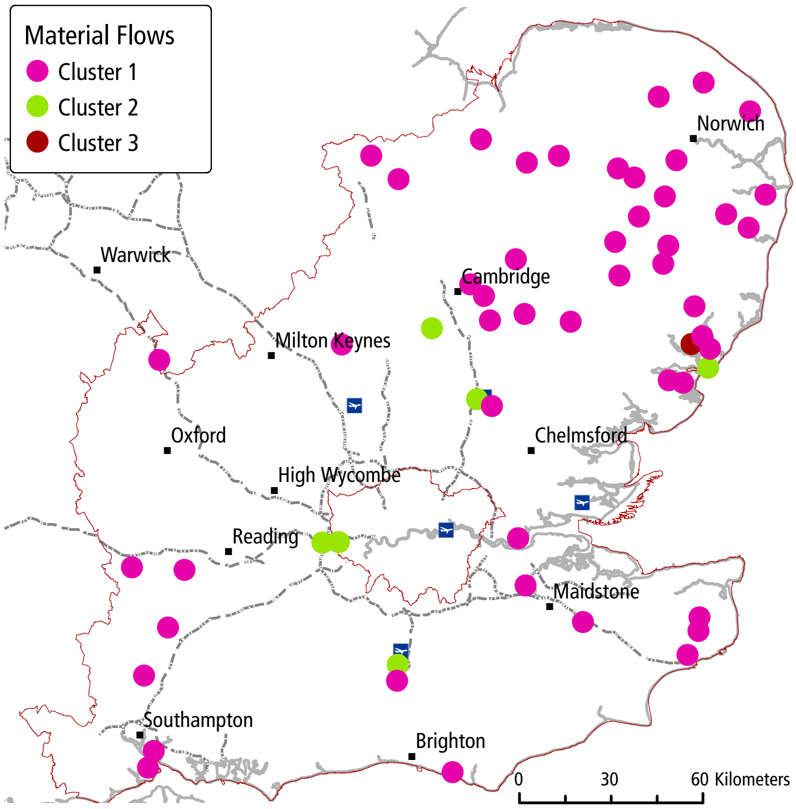


Figure 7.36: Material Flows Group Eigenplace Results

features. A quick glance at the representative signals in Figure 11.30 (see page 454) shows enormous variation, not just in the magnitude of the signals, but also in their timing. Perhaps unsurprisingly, the best selection comes from Cluster #2, which clearly contains several locations associated with the international movement of freight: two airports and a port form part of this group.

Rather more interestingly, this process also groups with these locations two PXAs with little obvious reason to have comparable flows. In fact, the site in this cluster that is near Cambridge throws up an issue similar to the one identified in the previous section: it transpires that this area contains both major construction works *and* several technology parks and so we may have a degree of confusion here. So although we constrained the eigenplace process to operate solely on large volume callers, there is no guarantee that the LQ and employment percentage filtering process used to select PXAs for additional study will pick areas with significant employment only in the sector of interest. While not significant enough to warrant inclusion in the Analytical group, the office park may still be large enough to leave a measurable impact on aggregate calling.

Summary

In Chapter 2, I had discussed the impact of congestion and poor infrastructure on the possible rise of the aerotropolis (Kasarda, 2000a,b). However, what is clear at this point is that airport access seems to be important principally for Logistics activity (see Figures 10.11c and

10.32e on pages 372 and 395), and that the only other sector with even limited evidence of this need is ICT. Away from this particular case, Logistics shows a bias towards the Northeast of the GSE that would be consistent with a preference for cheap land and labour. However, we should also note the high concentrations of employment around the M25 which leads me to suspect that, in spite of frequent congestion, the orbital acts as a staging area for metropolitan London.

From a communications standpoint, there is more sustained interaction over weekends than we have seen elsewhere, except tourism areas, but much as with the Analytical firms, the levels of international calling are surprisingly low when we take into account the scale of the supply chains that keep Britain fed and entertained. The wide variation in communications activity makes testing my predictions difficult, but there is a suggestion of a link between more sophisticated types of manufacturing and R&D centres, especially around Cambridge. This could be taken to indicate that complex production processes, including prototyping of the sort described by Scott (1983b) in Los Angeles, still require frequent interaction in spite of, for example, the supposed impact of the electronic data exchange and 3D printing for example (Economist, 2011). This could also be a sign that 'high-tech' production is being triggered here by spin-offs from the Cambridge research centres, and that the firms possess a locational inertia that creates path dependency in the later evolution of the industry.

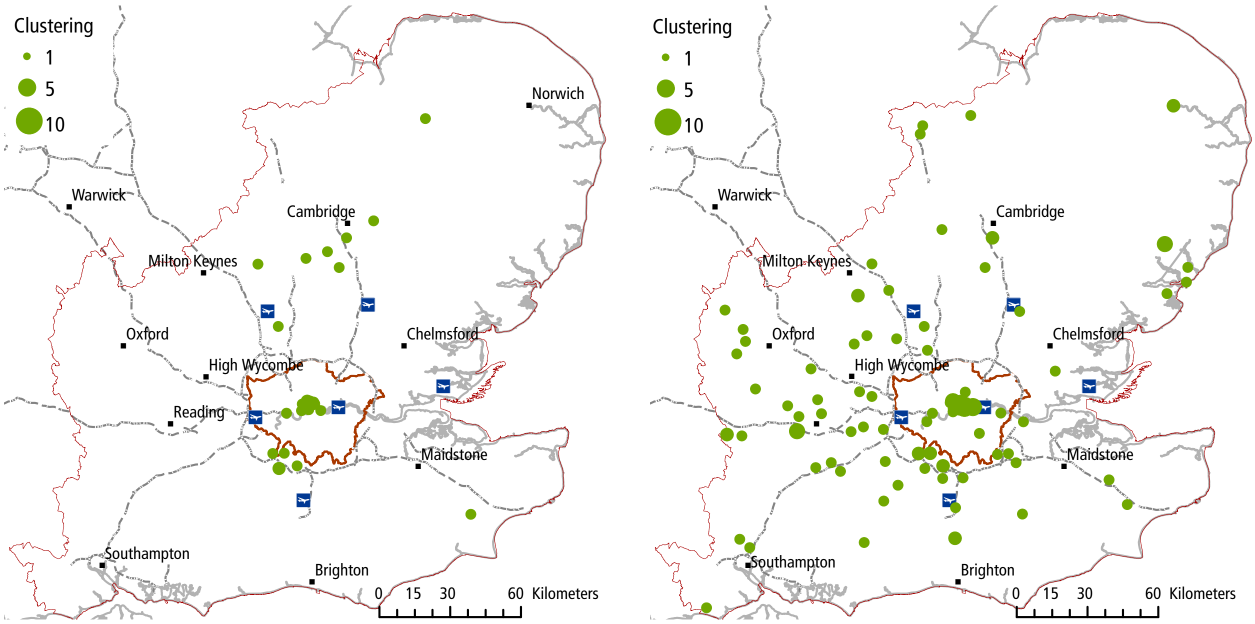
7.10 Combining Knowledge Bases

In the final part of the Analysis, I wish to recombine the industrial geographies considered in the five preceding sections above and to explore the larger locational and communicational dynamics since we have, until now, treated each one in isolation. The objective here is to see whether an integrated perspective will bring out new insights, or if it simply reflects the knowledge developed so far through Location Quotients, Telecommunications Quotients, and Eigenplaces.

Spatial Distribution

I have argued in Chapter 4 that clusters can be distinguished from mere agglomeration by the proximity of firms employed in fundamentally *different* types of knowledge work, giving them exposure and access to varied informational inputs. However, the maps on the preceding pages have not made it easy to see where one or more industries overlap, especially since the selected 'significant locations' were designed to (ideally) exclude other sectoral activity. So in Figures 7.37a and 7.37b I have deliberately relaxed these original criteria in order to take in the bigger picture.

These two maps show *only* those locations where more than one sector has a statistically significant LQ. The size of the circle is proportional to the number of sectors with statistically significant LQs in the PXA. As with the earlier maps, to determine significance I took the logarithm of the LQs, and then selected any PXA where the standard deviation (σ) was greater than 1.5 in at least two separate groups. Because of the number of calculations involved, and because the previous work had shown that many of these sectors were lognormally distributed, I did not suppress or otherwise control for the few sectors which had not shown a lognormal pattern of activity. I also did not enforce the 10% employment threshold requirement since just three of the original 'significant locations' had overlapping knowledge bases.



(a) Knowledge Base Cluster Locations

(b) NOMIS4 Cluster Locations

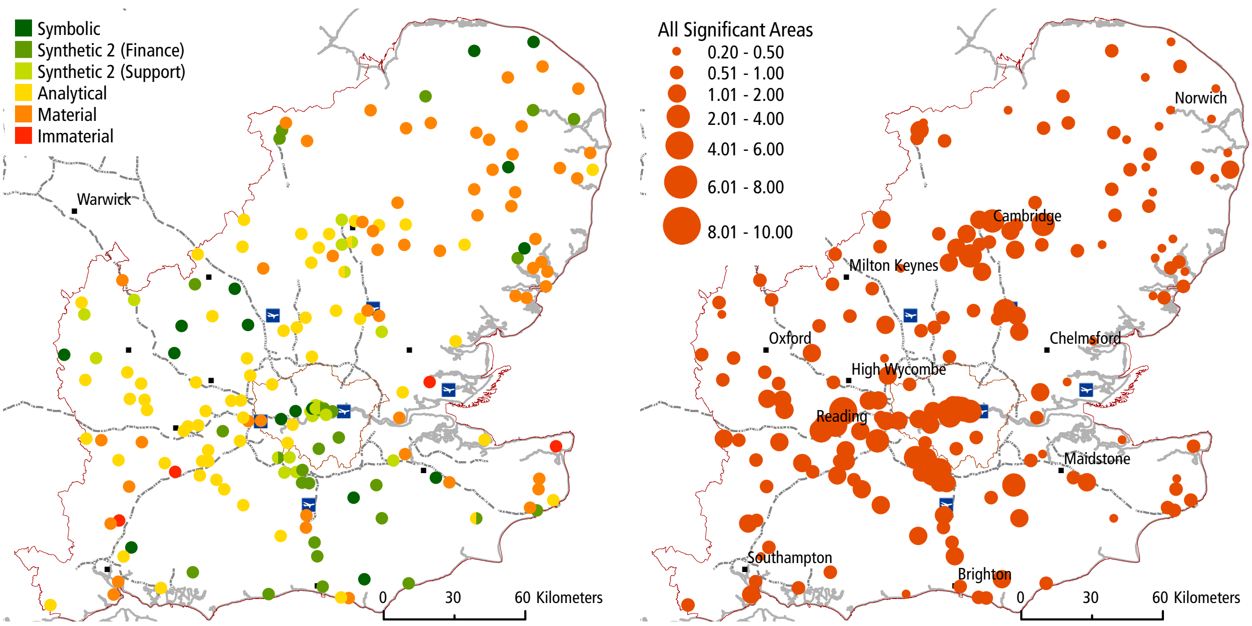
Figure 7.37: Number of Overlapping Sectors by PXA

Figure 7.37a uses the five knowledge base groups—Symbolic, Synthetic #1 (Finance), Synthetic #2 (Professional Services), Analytical, and Flows—to show that there are three clear spatial clusters of particular prominence: the London CBD, the Southwestern edge of the M25, and in the vicinity of Cambridge. Clearly, the existence of the M25 cluster is influenced by the impact of dividing the Synthetic group in two; however, the co-occurence between these two groups—which have, after all, little need to overlap quite so intensively—is remarkable. It also seems significant that the composition of the Cambridge cluster is quite different: it contains PXAs with predominantly Analytical and Flows employment.

However, both of these areas seem comparatively specialised when compared to the exuberant diversity of activity contained within London's CBD—firms from every major knowledge base can be found here at significant levels. In a few cases, all four categories can be found above the $+1.5\sigma$ threshold. Interestingly, Material Flow concentrations only seem to overlap with the core knowledge categories within a single PXA that is far from London. The value of Figure 7.37a therefore lies in the fact that it highlights areas with statistically significant activity across a very broad range of activities and thereby picks out areas where proximity may be driven by factors *other* than specialisation or vertical agglomeration. Figure 7.37b then fleshes out this picture using all 53 of the selected NOMIS4 employment categories to provide a broader view of all locations where distinct types of knowledge work co-occur.

Unsurprisingly, London's CBD emerges, again, as the dominant centre of Figure 7.37b, but the dynamic that should be abundantly clear here is that there is much more overlap of employment in the sectors that I chose to study in this work to the West and South of London than there is to the North and East. The clear implication is that the Western and Southern edges of the M25 are absolutely critical to the wider regional economy since there are particularly sizeable concentrations of *several* sectors near Reading, Redhill, and Haywards Heath/Burgess Hill. To the North, the Cambridge cluster has been substantially reduced in spatial extent, though expanded in industrial scope. We can also clearly see the impact of accessibility on this type of work through the radial distribution of the more narrowly focussed clusters.

Communication Activity



(a) Significant Locations

(b) TQ Results

Figure 7.38: Significant Locations and TQ Results

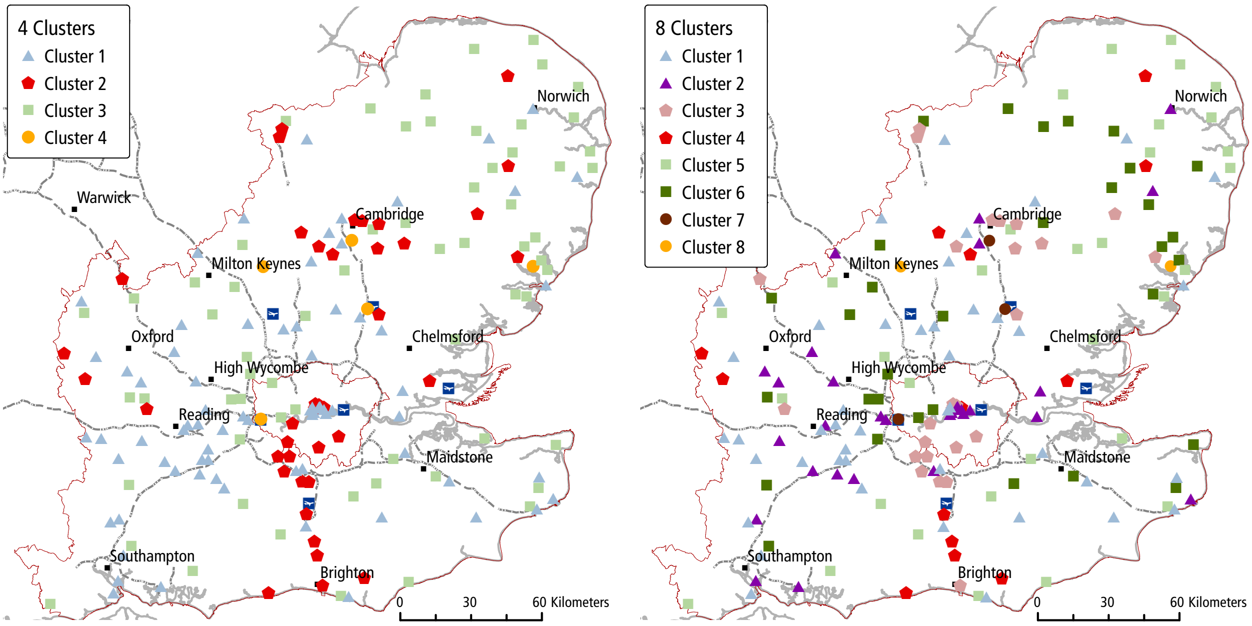
Returning to the original 184 significant locations, we can now consider the extent to which patterns of telecommunications activity are, or are not, distinct when cast into the larger mix. Figure 7.38a shows the complete map of significant locations as a reference point, reinforcing our understanding of how knowledge work is distributed across the GSE: some financial and symbolic work is tightly clustered in the centre of London, and the rest is distributed to the South, the Northwest, and the extreme Northeast; Professional Services and Analytical work has a strong Westward orientation, with a secondary cluster around Cambridge; Material Flows dominate East Anglia, the airports, and the seaports; and Immaterial Flows have no obvious logic other than that inferred earlier from their distribution within London.

The TQ results in Figure 7.38b are not surprising, but they are nonetheless significant since they emphasise the extent to which relative international calling intensity is disproportionately concentrated in a small number of regions within the GSE: Central London, Reading, Epsom/Redhill and Cambridge. We should also take note of the general decline in international call volumes heading into East Anglia from Cambridge, in the vicinity of Milton Keynes, in East Kent, and beyond Oxford. Taken together, these trends suggest a clear boundary for the globalisation processes expected of knowledge-intensive firms, especially MNEs. The leading edge of this process may be much further from the CBD than sometimes imagined, it is also far from being the entire GSE. Again, the ease of interpreting the TQ analysis suggests that is has real value as an analytical tool in spite of the absence of a temporal dimension from this view of the data.

Figure 7.39 presents the results from a KDDi approach to the eigenplace analysis. In each step of the analysis, the number of clusters is doubled, yielding two, then four, and then eight discrete clusters. For brevity, the results of the first clustering are not presented here; however, the results in Table 11.8 (page 455) suggest that decomposition process has produced a good mix of useful features and that there is relatively little to choose between in terms of the viability of two or seven clusters. The silhouette plot emphasises the consistency of the clusters, and the representative signals in Figure 11.31 suggest that a principal deciding factor has been the magnitude of domestic and international calling.

Taking Cluster #1 from the first analysis, and submitting only the PXAs assigned to that cluster to a new eigenplace analysis, we now find that two clusters is the optimal outcome but that the increasing number of features selected indicates that the selection process is having more difficulty extracting distinctive behaviours. The larger number of features also means that more substantive differences are identified during the k-Means clustering, and so while Cluster #1 in Figure 7.39a is fairly coherent, Cluster #2 contains some wide variation. The representative signals for Clusters #1 and #2 help to explain this dichotomy: Cluster #1 contains PXAs which have a strong afternoon surge in international calling, while Cluster #2 shows much more obvious noise.

The same process, when applied to Cluster #2 from the first cut of the data, suggests that this group contains a small number of PXAs with very different behaviours, and the silhouette plot (page 309) highlights this. Cluster #3 now shows obvious bias in international calling, but has a strong drop-off in afternoon domestic volumes, while Cluster #4 is defined principally by its massive surges in domestic and international calling, though not at the same PXAs! Broadly speaking, this second pair of clusters seems to allow us to distinguish between two types of areas, neither of which seems to have a particularly strong reliance upon *intensive* telecommunications, based largely on the small number of PXAs with abnormal levels of calling activity.



(a) 4 Clusters

(b) 8 Clusters

Figure 7.39: Significant Eigenplaces Results

Geographically, Figure 7.39a's four clusters break down in an interesting manner: Clusters #1 and #2 are clearly connected to the PXAs with high TQs covered in Figure 7.38b and, as such, can be implicitly connected to the activities of MNEs. Tentatively, their different dispositions suggest a rough hierarchy: Cluster #1 is generally the more central of the two (note the densities in Central London and Cambridge), while Cluster #2 suggests marginally less information-intensive activity in terms of the magnitude of interactions. Cluster #3 is, perhaps, more easy to describe in contradistinction to Cluster #4, which picks up calling activity at Heathrow and Stansted together with altogether more puzzling activity near Cambridge and Bedford. Accordingly, we can roughly categorise Cluster #3 as encapsulating the 'background' economy from a communications standpoint—this is not to suggest that these areas *don't* have international interactions since, as we'll see on page 313, the GSE as a whole is more informationally active than most of the rest of Britain. Rather, I wish only to emphasise that these areas are much less intensive users of telecommunications infrastructure than their 'neighbours' in the other clusters.

We can, if we so choose, redouble the analysis by taking each of the four clusters extracted in the previous round of processing and submitting them to a new round of eigenplace analysis (see page 459 for the representative signals and clustering results). This step produces the map shown in Figure 7.39b, enabling us to elaborate on the interpretations advanced in the preceding paragraphs. In this figure, Clusters #1 and #2 visibly differentiate between the main offices of global, and especially American, MNEs with a strong informational exchange component (Cluster #2), and the offices of firms with substantially less American influence as well as less domestic calling intensity. Similarly, Clusters #3 and #4 appear to elaborate a distinction along the international axis—the domestic dynamic appears similar for both groups—between what we might term 'core' back office facilities (again, of predominantly American firms) in locations such as Croydon and around the M25, and a range of facilities further out that appear much less involved in trans-Atlantic interaction.

Applying the same process to the remaining two clusters from Figure 7.39a yields more ambiguous results (see also page 461): Clusters #5 and #6 are distinguished mainly by their domestic call volumes, since both lack an international pattern that would suggest an obvious affiliation with another part of the world. What *is* noticeable about both of these clusters is that they experience much less of a drop-off in calling volumes over the weekend. So, unlike the highly internationalised firms operating in the PXAs considered in Clusters #1--#4, firms in this group operate on more of an 'around-the-clock' basis, with the intensity of calling offering the suggestion that we are seeing here a distinction between more and less intensive production and coordination sites. Note that Cluster #5 is in most cases on the periphery of the GSE, while Cluster #6 tends to co-occur with areas of more intensive activity in other clusters. Clusters #7 and #8 are rather more perplexing, especially since they already had quite distinct patterns of communications in Figure 11.32 (page 458). It is the location of the PXAs in this cluster that give them away: two are at airports, and one of the remaining PXAs seems to be port. So Cluster #7 contains strong domestic and international call volumes, which is consonant with their placement at major airports, while Cluster #6 has uniquely strong domestic interactions which, more than any other group in this analysis, appear to indicate hubs—*e.g.* a call centre service—of some sort.

In sum, the results are hardly conclusive since it transpires that the differences between the observed signals for significant locations are such that several clusters contain only one or two PXAs, while others contain dozens. However, we can tentatively conclude that the operations of some firms, and most especially of logistics and call-centre type operations, *do* have distinctive and measurable impacts on *per phone* calling levels at the finer scale. The communications footprint of U.S.-based MNEs is also particularly obvious in the representative signals but, given the obvious importance of America in the total flows mapped out in Figure 9.1b (page 339), this too is hardly surprising.

Distance Decay

A final dimension of calling behaviour that we can examine is the relationship between distance and call volumes. It has been previously demonstrated that, in aggregate, call volumes between any two points within a country can often be predicted using a variation on Newton's law of universal gravitation (Krings et al., 2009). The 'gravity model' of telecommunications holds that total call volumes are given by the formula:

$$V_{ij} = \alpha \, \frac{P_i \times P_j}{d_{ij}^n}$$

Here, P_i is the number of phones (or people) in PXA i and P_j is the count from PXA j. The product of these two populations is divided by the distance d_{ij} between them, raised to some power n, and all of this is then multiplied by a constant α to obtain the predicted flows. Using a similar approach, Krings et al. (2009) obtained a distance exponent of 2, and a gravitational constant of 1.07×10^2 seconds per day.

Here, since we already have the total flows from the data set, the objective of this part of the analysis is to understand how well this model fits real world data. We can make the results easier to analyse by rearranging the equation to give us a linear relationship:

$$\log \alpha - n \log d_{ij} = \log V_{ij} - \log (P_i \times P_j)$$

In this new equation, the y intercept is given by $\log \alpha$ and the slope of the line (if any) by n. Conceptually, the y intercept is the volume of communication when distance is 0, which in this case would be the predicted volume of calls within the PXA. The slope gives us an indication of how quickly this volume of calls drops over distance, all other things being equal. Note that we expect the slope to be negative, meaning that communications volumes decline with distance. A fuller explanation of this process, together with the analysis and figures that generated the summary results presented in Table 7.11, is given on page 464.

	Gradient	Intercept	Details	Normalised Reprojection
Knowledge Bases				
Symbolic	-1.198	+3.776	Page 465	
Synthetic Group #1	-1.203	+3.781	Page 466	
Synthetic Group #2	-1.150	+3.174	Page 467	
Analytical	-1.504	+6.994	Page 468	
Material Flows	-1.619	+8.781	Page 469	
Nomis-based Subgroups				
Cultural Production	-1.120	+2.764	Page 470	
APS	-1.160	+3.217	Page 471	
Legal & Accountancy	-1.143	+3.100	Page 472	
Consultancy	-1.199	+3.608	Page 473	
R&D	-1.658	+8.972	Page 474	
ICT	-1.640	+8.645	Page 475	
Logistics	-1.223	+4.295	Page 476	

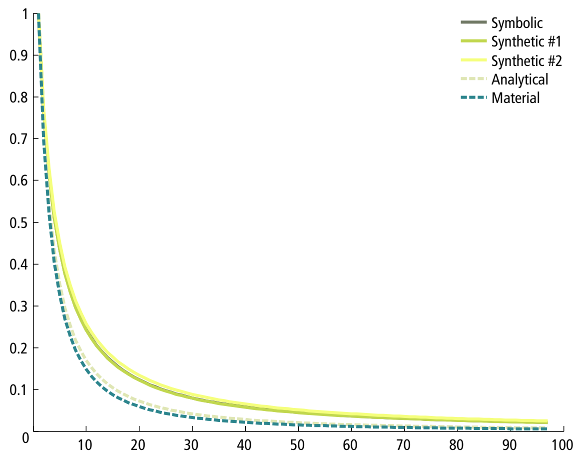


Table 7.11: Derived Intercept and Slope by Type of Knowledge Work

Table 7.11 suggests the existence of two markedly different groups. The first group, composed of the Symbolic, Synthetic #1, and Synthetic #2 Groups and their various subgroupings (Cultural Production, APS, Legal & Accountancy, Consultancy), has a negative slope in the range of $-1.20 \leq n \leq -1.15$ and an intercept in the approximate range $+3.20 \leq \alpha \leq +3.80$. The second group, composed of the Analytical and Material Flows groups, together with the subgroupings of R&D, ICT, and Logistics, have a much steeper slope ($-1.50 \leq n \leq -1.70$) and a much higher intercept in the range $+6.90 \leq \alpha \leq +9.00$.

Counterintuitively, what this suggests is that firms in the Analytical and Material areas spend a great deal more time talking to people locally than do the firms in Symbolic or Synthetic PXAs. More work will be required to understand whether this is because of the predicted substitutive effect or if some other dynamic is in play. In other words, are workers in Analytical environments apparently talking more *because* they are able to exchange information electronically rather than meeting F2F? What is promising here is that this bimodal distribution is similar to the broad categories identified in the eigenplace analysis, suggesting that R&D and ICT do, in fact, have a great deal in common communicationally. The fact that the Synthetic and Symbolic groups—which are associated with more extensive F2F interaction and less codification—are so obviously similar in behaviour here (as they are in the eigenplace results) suggests a similar set of factors influencing their use of telecommunications. Additional work would be required to understand the shift in the observed slope and intercept in the transition from 'Material Flows' to the narrower 'Logistics' group.

The Big Picture

The rich data from Britain has enabled us to expand upon the approach outlined in Calabrese et al. (2010): we found that multi-stage (KDDi) and filtered clustering approaches could deliver additional insights by progressively eliminating irrelevant data. Through normalisation by the number of phones, and in combination with the eigenplace method, it becomes possible to zero-in on finer and more meaningful variations, but more research is needed to understand which types of normalisation, filtering, and clustering deliver the best analytical results. I remain, as I will detail in the conclusion to this chapter and in the Reflections section (page 326), unconvinced that *k*-Means clustering is necessarily the best approach, though it was certainly the right one to take in this early work.

Regardless, the significant location-filtered eigenplaces highlighted a Western bias for a great deal of international calling activity (*i. e.* that firms to the West of London place more international calls than anywhere except the CBD), and this finding is entirely consonant with long-standing research into the 'Western Wedge' (Hall, 1987). This tendency was especially pronounced for the ICT and R&D sectors, but was common across nearly all sectors. However, we need not stop this work the GSE scale, and Figures 7.40a and 7.40b point towards the next step in the development of the eigenplace approach: this last data set is much larger than anything previous analysed using this technique, but the results visibly demonstrate that it copes well with wildly varying volumes from multiple input data streams.

What makes these figures important is the clear hierarchy captured by the dual-analysis of international and domestic volumes. This is exactly what we would expect if, as we saw in Figure 7.16, many businesses tend to use the phone domestically in broadly comparable ways, but internationally-oriented businesses place and receive calls in a mea-

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(a) 4 Clusters

Figure 7.40: British Eigenplace Results (Volume/Phone)

surably different manner. The key point, however, is that we have used an automated process to extract and categorise this information—it is neither an artefact of the data, nor the product of a basic bias in feature-selection or factor-analysis.

In the past three years, the eigenplace analysis has scaled from a limited test for a single city (Reades et al., 2009), through a larger analysis of a university campus involving many more data points (Calabrese et al., 2010), and now to the exploration of an entire country and its telecommunications usage. At this last scale, we see results that would tend to support the work done by Eagle et al. (2010) that sought to connect deprivation to diversity in social networks. However, the eigenplace analysis gives these an explicitly spatial cast, as evidenced by the 4- and 8-part categorisations, in which low (on average) domestic volumes and very low (on average) international volumes seem to map on to areas of England, Scotland, and Wales known to suffer from economic deprivation.

However, the link between economic activity and internationalisation in not simple and merits further research. For instance, the top two clusters in Figure 7.40b correspond, within the GSE, to PXAs that emerged—again and again—as the sites of MNE operations. And the density of the top three clusters reinforces the idea that this type of globalisation is a dominant feature of the South, and that it is having, with the notable exception of Edinburgh, a more limited impact North of Warwick. This implication is more obvious in Figure 7.40a, in which the lower two volume clusters clearly map on to parts of Devon, Wales, the Northeast and Northwest of England, and the Highlands.

There are, however, two points worth noting about the eigenplace approach which place some important constraints on how the results can be interpreted. More work is needed to understand the comparability of the results, as well as whether there might be a means to derive results that are more directly comparable across countries or regions. The second weakness is that a good deal more work will be needed to determine whether there is a definitive correlation between the eigenplaces and business or non-business activities. The evidence to-date suggests that the eigenplaces pick up many of the dynamics at work, and enable us to quickly extract areas with distinctive, highly-concentrated sets of activities (see page 430 for an application to residential analysis), but whether this approach can be used in the *absence* of, say, Census or NOMIS data remains an open question.

7.11 Conclusions

In the Prediction & Empirical Verification portion of the Methodology I put forward a series of predictions for how the theory developed in the preceding chapters might be borne in out in locational and communicational behaviours. These predictions were rooted in the typology of knowledge work advanced in Figure 6.1, which suggested that the choice of location would be influenced by three factors: the degree of ubiquity or localisation, the degree of creative or role work, and the degree of multilateral or bilateral interaction. It is now time to review this typology in light of the evidence developed over the course of this chapter.

Ubiquitous & Localised Information

I have argued that inputs with the characteristics of a ubiquitous good would have much less impact on firm location than localised inputs. Consequently, I anticipated that firms operating in ubiquity-oriented sectors would exploit increasing infrastructure flexibility to reduce costs, while firms reliant upon localised knowledge transfers would prefer to locate at 'central' locations near to major transport nodes or to the sectors upon which they depend for inputs. Furthermore, I then suggested that this behaviour would be expressed in the telecommunications data in the following manner: firms working with ubiquitous inputs would make greater use of the phone to communicate with more distant suppliers, while their compatriots working with localised inputs would interact with far fewer areas.

At the coarsest level, the evidence for this first pair of predictions was surprisingly mixed. Logistics and manufacturing, whether considered together or separately, were clearly influenced by the available infrastructure in each area and demonstrated a preference for more 'remote' but well-supplied locations. The key exception to this rule proved to be those most of inflexible of infrastructures: the international airport and deep-water terminals. So in spite of the high cost of land in the vicinity of Heathrow, the area is dominated by logistics providers, and the importance of Felixstowe can be estimated from its massive concentration of employment in this sector.

So in terms of location, the industries involved in the creation and movement of physical goods seemed to fit well with the more nuanced theory developed in Chapter 3. Where the prediction proved much less accurate was in terms of this sector's impact on communications: although many sites had more modest levels of telecoms usage, four locations were constantly selected by the eigenplace analysis on the basis of their uniquely unbalanced communications patterns. These four sites—Heathrow, Stansted, Felixstowe, and Bedford—evidently act as major nodes in a global supply chain, and leave correspondingly massive footprints in the communications infrastructure. Paradoxically, however, this impact is not on international calling—though it is still substantial—but on domestic volumes.

The second area where I expected ubiquity to be a factor was in the case of analytical firms such as those involved in ICT and R&D. And although the locational differences between these two sectors might be expected to be marginal—both industries are broadly organised around codifiable knowledge and the activities of many small firms and a smaller number of MNEs—the NOMIS data suggests otherwise. The 'Western Wedge' of ICT-related employment has been particularly visible throughout this work. The data suggests that employment is localised along and between the westward M-class roads from London, but not clustered in any traditional sense.

In contrast, R&D firms showed much greater dispersal, with statistically significant concentrations of employment emerging in places as far removed from London as Sandwich and Wellingborough. These locations suggest much less reliance on information exchange with other sectors, and far more self-containment, though this is not necessarily surprising since the purpose of primary R&D is to develop market-leading technologies, methods, and drugs. More than any other knowledge-intensive sector, R&D firms appear to be making the most of ICT to remove themselves from urban locations.

As a result, it is hardly surprising to find that these firms appear to make extensive use of telecommunications. They do not, however, use it so much to interact with other firms in the area as to communicate with (one presumes) their sister offices overseas. The evidence from the TQ analysis supports this conclusion: R&D areas had amongst the highest international TQs of any sector studied. The evidence therefore suggests that the analytical base as a whole comes closest to operating in a kind of global/local network whereby knowledge is locally-generated but can be effectively transferred through long-distance arrangements[14]. In short, although it seems that distance is no obstacle to globalised R&D firms, equivalent ICT companies appear to show a slightly stronger preference for proximity to airports and to clients in London (see also Buck et al., 2002, p.117) which suggests an ongoing F2F interaction requirement.

[14] Matson and Prusak (2010, p.4) report the example of a pharmaceutical firm that designated a small group of researchers its 'knowledge intermediaries'; they are tasked with summarising key findings from new research and submitting them to an internal database. This same approach would have little relevance to, say, which directors might be interested in a project, or which actors might be 'right' for a particular role.

Creative & Role Work

In Chapter 5, I defined creative work as having to do with the generation and dissemination of new knowledge, be it symbolic, synthetic, or analytical. So by contrasting the distribution of creative and role- or rule-based employment and communications, I am trying to determine whether new knowledge arises at particular points in space, or through particular interactions across space. The working hypothesis has been that the value attached to creative work by knowledge-intensive firms implies that their location and communications patterns will, in aggregate, leave a measurable imprint on activity in the GSE from which we can develop a composite portrait.

In Chapter 5, I also suggested that the locational requirements of the most valuable creative workers would tend to trump those of rule- and role-based employees since, from the firm's standpoint, the 'creative class' was the least flexible link in the knowledge-creation and dissemination chain. The result of this dependence upon the preferences of employees would be the dominance of knowledge-intensive over rule-intensive firms (or divisions) in high-amenity parts of the GSE. However, I also noted (see page 129) that there seem to be two competing trends in the definition of household amenity: for some workers it is expressed as a preference for the 'tamed rurality' of the well-heeled countryside, but for others it seems to manifest as a preference for the riotous social life of large cities.

Since I have generally prioritised the study of knowledge-intensive sectors in this thesis, it is relatively easy to compare the locations predicted in Table 6.2 with their disposition and relative concentration in space as measured by the LQ. The absence of more rule-based sectors such as manufacturing from the city centre, or even from much of the area within the M25 or the West of London (see Figures 10.26e and 10.26f on page 387), offers negative evidentiary support for this hypothesis insomuch as it seems that the greater the component of the role- or rule-based work in a sector, the greater the likelihood that employment concentrations in that sector occur at more peripheral, and frequently less desirable, locations.

For positive support for this hypothesis we must return to the idea that symbolic work, because of its strong social component, would tend to occur in cities, while synthetic work, because of its iterative component, would tend to prioritise accessible locations. In contrast to both of these, analytical knowledge creation was expected to occur in other sorts of high-amenity areas since there is no pressing need for proximity or frequent F2F interaction. Since we have already seen that R&D and ICT firms are significantly more dispersed than their symbolic and synthetic counterparts, this last part of the prediction is the easiest to confirm. The locational pattern of symbolic work also proves relatively straightforward to verify: at both the London and GSE scales, knowledge workers tend to accumulate at relatively high densities in a disproportionately small number of locations. Significantly, as we narrow the focus from the broader Symbolic Group (Figure 10.28a on page 389) to the more fine-grained Cultural Producers Group (Figure 10.31a on page 394), the concentration of workers is accentuated in Central London, and only a few significant locations remain outside of the M25.

It is the Synthetic Group, and in particular the financial services field, that proves the most problematic from a locational standpoint: although there is ample evidence of employment concentrations along highly-accessible motorways and in less congested towns around the GSE, the highest density at most levels of aggregation and across most industrial groupings remains the City of London and Canary Wharf. This pattern of synthetic activity suggests that there must be another dynamic of knowledge creation at work here, since if we were to naïvely take the LQ data at face value we would naturally presume that the most valuable work is being done at the seemingly more accessible sites spread around the M25.

However, as I have noted at several points in this thesis, one of the long-standing problems of NOMIS data is its inability to distinguish between the types of work being done at different offices within the same firm. It is, for instance, widely known that in the financial sector a great deal of the more routine, rule-oriented work has been relocated to back office facilities, while a good deal of the highest-value, most creative work has remained in the CBD. What we found in the telecommunications data simultaneously confirms the 'big picture', while calling for clarification at the finer scale.

One of the most visible features of the TQ analysis undertaken on page 289 is the way that PXAs dominated by *both* types of synthetic work become disproportionately international in their use of telecommunications as we move closer to the CBD. Two groupings stand out in particular in the TQs—the City of London/Canary Wharf, and Epsom/Redhill—but the differentiation becomes even more stark in the eigenplace analyses on pages 291 and 292 since in both cases there are clusters whose members are found *only* within Central London. The representative signals only reinforce this view of the importance of the City and its immediate surroundings.

However, a more nuanced approach reveals that the most internationalised areas where synthetic knowledge is employed often use domestic telecommunications *less* than some of the other clusters extracted from the eigenplace analysis. So although the general lack of high-level internationalisation much beyond the M25 is significant, and would fit with the existing KIBS research (see page 183), this is not the end of the story. Similarly, the Symbolic Group's telecommunications activity suggests at first glance that internationalised communications largely ends at the metro-London border but, again, closer examination reveals significant areas of activity at some distance from Central London. In particular, Advertising work near Oxford leaves a significant footprint in the TQ and clustering analyses, suggesting that some types of creative work are no longer quite so dependent on proximity to the amenities of major cultural infrastructure.

As a result, the communications data enables us to refine the hypotheses advanced in the Methodology: we *can* say that creative work seems to coincide with intensive telecommunications use since this has everywhere been correlated with the presence of global firms and 'signifying' districts where market-making work is widely understood to be done. Given this, we also have strong confirmation of the basic validity of the knowledge bases approach itself, since for each of the three principal bases, the pattern of intensive telecommunications usage generally follows our understanding of how workers in each group are likely to define 'amenity': dense, urban environments for cultural producers, and spacious, idyllic environments for analytical workers. For synthetic knowledge workers, however, the picture remains complex since we know that many managers of leading consulting and banking firms live beyond the M25, and yet the communications evidence strongly suggests that the creative work in this base is being done in Central London, which is comparatively congested and inaccessible by private vehicle.

Multilateral & Bilateral Interaction

The explanation of this puzzling dynamic lies, as I have argued extensively in Chapter 5, in the distinction between multilateral and bilateral interactions, especially when they are undertaken F2F instead of electronically. The expectation here is that knowledge work which relies upon the input of diverse groups will tend to occur in CBD locations since, even though they are congested and expensive, the city cores place many different specialisations in close proximity to one another and enable meetings to be organised frequently as well as on short notice. In contrast, where interactions are bilateral, the prediction from Table 6.2 is that they will take place over longer distances because the cost of coordination and meeting will be lower.

Looking back at Figure 7.37 (page 306), we can see clear evidence in support of this claim: the greatest sectoral overlaps occur in the City and West End, while the rest of the GSE shows decreasing overlap as we move away from Central London. The value of splitting the Synthetic Group in two, and of further subdividing the Professional Services group into finer-grained distinctions between Engineering, Accountancy, Business Consulting, and Legal Services is now clear since, although both the synthetic and symbolic bases have a greater reliance on direct, F2F interaction, the degree to which synthetic knowledge work is associated with bilateral or multilateral interaction varies significantly.

Generally speaking, 'high finance' behaves much like cultural production in terms of its reliance on intensive multilateral flows, while Engineering and Accountancy tend to behave much more in line with my predictions for bilateral interaction since they can be found at locations from which the rest of the GSE is readily accessible. The eigenplace map for Synthetic Group #2 (Figure 7.27 on page 292) highlights this dynamic: the areas of significant activity are widely dispersed, but all are based on M-class roads or near to clients in Central London. The bimodal distribution suggests that the firms in the centre are catering to a global clientele with extensive and complex interaction requirements, while those further out are dealing with regional (though still international!) concentrations of demand from other industries.

Another piece of evidence in support of this conclusion is the noticeable group of less international, but still clearly agglomerated, APS firms in the vicinity of Cambridge. More than any other city outside of London, this town appears to possess a diverse mix of sectors—Synthetic, Analytical, and Material—all of which have important concentrations in the vicinity. Note too that this pattern contrasts in significant ways with the greater specialisation of Reading in analytical activity, and that this is reflected in the insights that emerged in Figures 7.39a and 7.39b (page 309) from the communications data: the area around Cambridge is much less 'oriented' towards America than the Western Wedge in terms of international call volumes and timings.

What this finding suggests is that, in contrast to the other groups, analytical knowledge work operates quite differently and without the need for frequent F2F encounters. The much steeper distance decay and higher intercept seen for the Analytical Group in Table 7.11 strongly implies that firms in these environments employ telecommunications as a *substitute* for F2F interaction, not a complement to it. This pattern of interaction helps to explain why 'science parks' should be seen as a weak foundation for localised development: these sites tend to be colonised by firms with little interest in encouraging the wider circulation of knowledge. Conversely, isolated cultural institutions, such as museums, are an equally problematic basis for development since they depend greatly on F2F interaction to stimulate symbolic knowledge generation.

Sectoral Dynamics

By pairing the results from the TQ and eigenplace analysis with the earlier findings from the LQ research, we have developed a stronger sense of how telecommunications and location interact for firms in different sectors. Returning now to the six core industries to which we have turned again and again in this research, we can put forward a series of conclusions that draw together the many theoretical and empirical threads developed over the course of these seven chapters.

In Table 7.12, I draw a distinction between internationally and less internationally-oriented firms so as to highlight the impact of globalisation on these firms' use of infrastructure. By this point the results should no longer be surprising, but they do serve to emphasise the degree to which London is not an isolated economy, but part of a much larger regional system, and to highlight the way in which differential locational patterns emerge as the result of the interactions between the informational inputs, the nature of the work, and the types of exchanges that these entail.

Sector	Internationally-Oriented	Less Internationally-Oriented
APS	Sites with near-instant access across multiple infrastructures to internationally-oriented clients; may be in CBD or edge-city locations	Sites with access via road and, to a lesser extent, rail in MCR sub-centres
Cultural	Inner-city sites; especially in areas near to collaborators/clients/patrons	Mid- to high-income, amenity-oriented towns or countryside with sufficient local demand
Finance	CBD sites with historical role in finance; spillover to 'inner edge cities' at locations with high accessibility for rail and air infrastructure within core metro area	Variety of locations depending on activity; often accessible by road and rail
ICT	Software-as-a-service may be CBD, similar to APS strategy; Software-as-a-product oriented towards high-amenity areas with access to air infrastructure	Amenity-oriented in second- or third-tier MCR sub-centres
Logistics	Major inter-modal sites; some supervisory activity in CBD	Sites accessible to road and rail; available space is primary concern
R&D	High-amenity sites with high-value complementary infrastructure (universities, ICT) and access to road infrastructure; modest air and rail access requirements	Amenity-oriented second- or third-tier MCR sub-centres

Table 7.12: Summary of Locational Strategies for Key Sectors

8
Conclusions

8.1 Introduction

We began this work by noting that planning has been largely blind to the infrastructure of telecommunications and to the relevance of a more nuanced grasp of 'telegeography' (Townsend and Moss, 2008, p.28). Over the course of the past seven chapters, we have developed the idea that understanding information flows is integral to understanding the spatial preferences of contemporary firms and, consequently, to designing appropriate urban and regional developmental policies for the coming decades. In this final chapter I will attempt to paint the bigger picture that this research has helped to bring into focus.

The overarching concern of this work has been the absence of a systematic attempt to synthesise thinking on locational preference and knowledge work in a way that is in tune with the requirements of policy and planning in the 21st Century. Approaching this subject has required traversing planning, economic, and sociological literature, but the results have proved to be remarkably consistent with the need identified by Hall (2003, p.148) for a 'new theory of location' that would "…start with a neo-Weberian model of the informational economy. On top of this would be superimposed a Christaller-Lösch system of central places, modified to take account of changes since they wrote…" So although I did not set out to consider the relevance of a theoretical tradition dating back to the late 19th Century, this is where the need to properly contextualise the impact of telecommunications on firms and upon urban form has taken me. I trust that the reader will have found the journey worthwhile.

8.2 Principal Findings

Literature Review

In Chapter 2, I argued that relative infrastructure flexibility is the appropriate lens through which to view locational preferences. However, at the fine scale this flexibility has unpredictable spatial effects that are bound up in the 'centrality' of places where many infrastructures meet. Increased flexibility might 'enhance returns at big centres and reinforce their lead', but may also enable smaller, specialised centres to survive by 'contesting only selected niches' (Scott, 2001, p.20). However, the risk for less developed regions is that the rising dis-benefits of increasing loadings—congestion, cost, unreliability, etc.—will overwhelm flexibility. The costly nodes and links of 'upper tier' infrastructure required to relieve these problems may ultimately follow existing rights-of-way, leaving less integrated regions behind and locking in existing patterns of centrality and peripherality (Garcia, 2002, p.40).

In spite of this risk, Garcia (*ibid.*) argues that "…the impact of today's network technologies will—to a considerable degree—be a matter of the social, economic, and political forces driving their evolution." But the fact that the location of nodes and links, and their accessibility are often ultimately political decisions also implies that we can think of flexibility not only as an attribute of networks, but also as an objective for planning policy. Flexibility involves tradeoffs between social, environmental, and economic factors, and it is up to us to decide what set of outcomes is desirable.

Turning to the firm in Chapter 3, I noted that traditional location theory was still able to shed a good deal of light on contemporary firm preferences provided that we could account for the increasing impact of informational inputs and outputs on the historical considerations. Recovering the notion of ubiquity enabled us to address this issue for some types of data, but information as a localised input could only be understood if we conceived of the underlying market as having characteristics that made it more or less 'searchable' or opaque.

The notion of opacity helps to explain why some firms are able to relocate over vast distances, while others remain firmly place-bound, and this too has important implications for policy: the 'services factories' that are often lured to the North of England by temporary tax incentives or expensive infrastructure provisioning rely almost exclusively on relatively transparent data and codifiable interactions. Consequently, such sites are in direct competition with equivalent facilities anywhere in the world and a lower price will often win the day. The government could, of course, mandate that sensitive financial information cannot be discussed with an operator beyond their jurisdiction, but a more pragmatic response would be to identify and exploit the advantages of local knowledge in more opaque—which is to say, more complex—interactions.

The constraints of opaque markets are therefore an important part of what keeps firms in cities, but as I argued in Chapter 4 we also need to consider the effect of lifecycle and scale on this dynamic. Quite simply, agglomerations provide shared access to infrastructure and services that would ordinarily be too expensive for a firm to procure on its own from a distance. However, clusters offer something more: in particularly opaque markets that rely on the character and ability of individuals, it becomes necessary to somehow find the 'right person for the job' when there are thousands from whom to choose.

For this reason, I suggested that the intense socialising that seems to characterise some industries—especially those, such as film and finance, with a highly customised and weakly scaleable output—is actually a way of managing what would otherwise be nearly insurmountable searching and matching costs. Furthermore, the diversity of urban environments gives individuals and firms greater exposure to novel information, which serves as a buffer against a sudden, radical change in style, technique, or technology. Against the diversity which supports innovation, however, we must balance a degree of coherence or, as I often termed it, proximity that enables successful communication.

So one critical impact of ICT and mobility on business is the way that they enable alternative types of proximity to weaken the requirement for copresence in translucent and opaque markets. The basic distinction between tacit and codified knowledge further enables us to understand why some types of work—programming and R&D, for instance—benefit from this dynamic while others—fashion and finance, for instance—do not. I then additionally refined this distinction through the application of the knowledge bases approach to contemporary work, and through this model we were able to see how telecommunications was having a differential impact on firm locational strategies at local, regional, and national scales.

Methodology

The aim of the Methodology was to situate telecommunications research within the emerging field of Computational Social Science (CSS), which is characterised by the adoption of techniques from the natural sciences for the analysis of large behavioural data sets. The Economist (2010a) argues that "revolutions in science are often preceded by revolutions in measurement…" but, historically, social science research has been limited by cost and complexity to small-scale surveys or to periodic large-scale collection. CSS completely rewrites this equation since collecting five billion records is no more work than collecting five thousand.

In discussing the spatialisation of information processing, Townsend and Moss (2008, p.28) note that businesses in world cities act as "importers of raw information and exporters of ideas, decisions and new services." As a result, we could easily anticipate that London would be a key axis of this research since it contains particularly high concentrations of knowledge-intensive firms and knowledge-enabled workers. However, not only did the use of traditional LQs highlight the need to look beyond London and into the GSE, it also emphasised the need to map inter- and intra-urban communications at the scale of companies in order to begin to understand the contemporary city and its economy.

In seeking to uncover these workings and map their resulting flows, I tested two novel indices of telecoms usage: the Telecommunications Quotient and the Eigenplace. Both techniques are very much Eulerian in their approach to urban studies, and they therefore keep the focus firmly on places, not people. The Eigenplace technique also appears suitable for other types of 'flow data': I cannot see any basic reason why it could not also be applied to commuter flows or Twitter posts—though clearly it is sensitive to the resolution of the underlying data and to the level of aggregation—provided that there is enough data to make for meaningful conclusions (cf. Batty, 2010). That said, it should hardly be surprising that the most exciting results in Chapter 7 emerged from the marriage of these novel methods with more traditional approaches such as the Location Quotient.

Analysis

Kleinberg (2008, p.66) suggests that "science advances whenever we can take something invisible and make it visible", and in Chapter 7 I sought to contribute to this process by presenting results that drew on the aggregate, anonymous, and entirely invisible activities of millions of people. The analysis sought to achieve two things: to identify and explore meaningful concentrations of industrial activity using a statistically sound methodology, and to use the 'significant locations' thereby extracted from the employment data as the foundation for an analysis of a telecommunications data set. As might be expected in such a case, the results have proved exciting, but not always decisive. I believe that both the TQ and the eigenplace approach have analytical value, but that more work will be needed to understand the particular domains in which their outputs are relevant and the constraints under which they can be employed successfully as research or policy-making tools.

By beginning with a 'naïve', unsupervised approach to telecommunications data we could test the 'global cities hypothesis' with greater rigour and find that, although there is a marked tendency for more central businesses to be more international in terms of their communications patterns, this is not the same as saying that *only* the businesses of the CBD are international in outlook. In some cases, internationalisation in calling behaviour appears to coincide with a movement out of the CBD and into accessible, high-amenity towns and cities such as Reading and Cambridge.

ICT and R&D offered the best illustration of how some knowledge-intensive sectors are today able to pursue much more flexible locational strategies. These firms tend to show higher levels of dispersion than the most global of cultural or financial firms, and they often seem to be at their most international when in proximity to transport-rich sites—especially airports—and to other globalised industries. More 'basic' fields, such as logistics and manufacturing, highlight the divergence between immaterial and materials-based industries. In the latter case, the areas with the highest levels of international calling activity are associated with inter- and multi-modal nodes—where ships dock, planes land, and rail and road meet—though high-tech manufacturing may be an important exception to this 'rule'.

The results lend empirical support to Castells' suggestion that "in terms of spatial networks…these global networks do not have the same geography [and] they usually do not share the same nodes. The network of innovation in ICT is not the same as the network of finance…" (2009, p.10). In short, the wider regional geography of back-offices and research parks is vital to understanding what is, and is not, happening in the CBD. So whereas Sassen (2002, p.15) has argued that "cities that are strategic sites in the global economy tend, in part, to disconnect from their region", I would claim the reverse: that the pre-eminent cities of the global economy are deeply connected to their 'hinterlands' and that they underpin a range of high-value activities that are equally global in outlook.

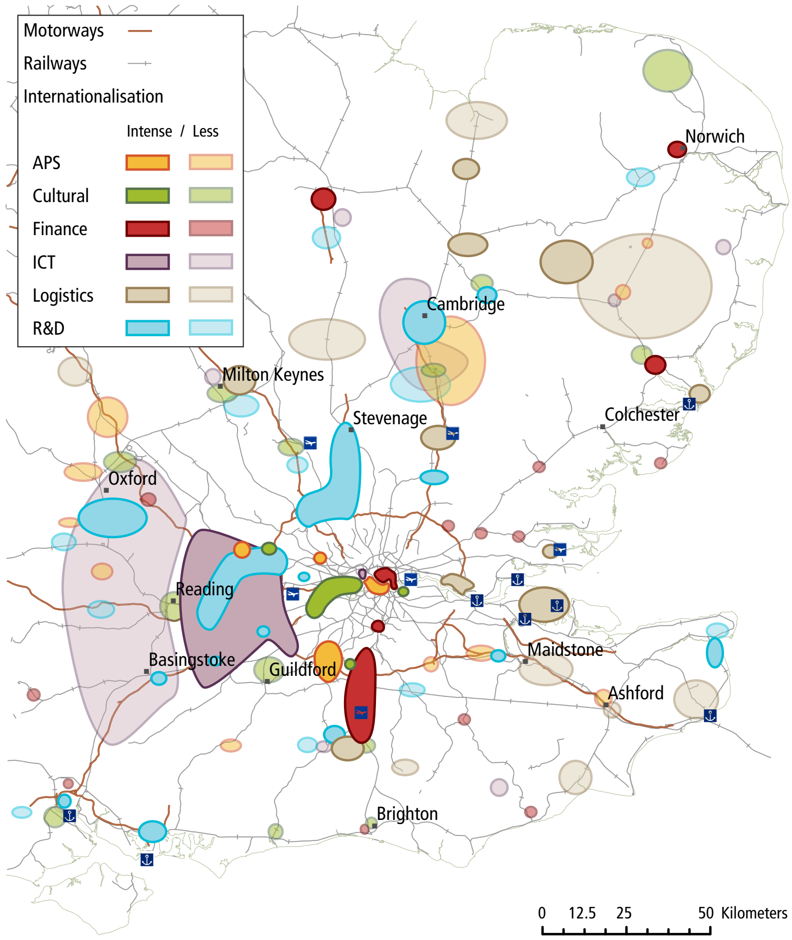

Figure 8.1: Summary of MCR Sectoral Distribution & Internationalisation

In Figure 8.1, I have combined the geographical distribution of the core knowledge- and flow-intensive industries examined in the course of this research with the results of TQ and eigenpace analyses. Although necessarily impressionistic to some extent, the figure makes clear that Breheny's (1999, p.175) suggestion that "London's role is to look both inward and outward to connect domestic and cosmopolitan networks of trade, information, and capital flows" is no longer strictly true. Sophisticated, highly-skilled activity is today spread across a broad swathe of the GSE, and much of it is highly international in outlook. The pattern of activity shown here, and summarised in tabular form in Table 7.12 (see page 320), nonetheless also indicates that there is, amongst leading firms in all fields, still a "…need for ongoing face-to-face contact, to sustain continuous innovation and reflexivity…combined with exceptionally high use of advanced telecommunications to link relationally and continuously with the rest of the planet" (Graham, 2002, p.77).

8.3 Reflections

Although the eigenplace approach has provided important evidence of the existence of different locational strategies for internationally- and domestically-oriented firms, this is only a first step. CSS analysis also holds out the possibility of detecting groups of firms that are interconnected by informational input and output relationships. Network clustering algorithms can be used to identify supply-chain linkages and interactions between front- and back-offices. I believe that the most promising approach for the next phase of this research will be the 'link communities' method recently outlined by Ahn et al. (2010) since it allows nodes (*i. e.* offices) to bridge two or more communities (*e. g.* procurement from specialised suppliers and management of production sites) and should thereby allow a more fine-grained investigation of the relationships between sectors within the London Mega City Region (MCR).

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(a) Unfiltered Network

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(b) Top 25% of Links by Volume

Figure 8.2: Network Map of the GSE

Ultimately, however, we should not forget that we are dealing with an immensely complex system whose behaviour is only graspable at the very highest level of aggregation. A LaGrangian representation of total flows on the communications network can demonstrate this in a simple way: Figure 8.2a shows every point-to-point link between PXAs within the GSE, and Figure 8.2b shows the network after the weakest 75% of links have been removed. The first figure is, quite simply, nearly illegible. But the second figure can be quite profoundly misleading since it gives the impression that no conversations take place between the more remote parts of the GSE and Central London. Naturally, taking the *per phone* volume of conversation would change the picture again, and in this case it would emphasise links along the coast and through East Anglia where, on average, people and businesses talk more to their neighbours than they do in urban environments where they tend to talk more widely.

In a very real sense, this is the critical challenge facing CSS research in general, and telecommunications research in particular. The issue is that, depending on how you cut the data, you will get different answers to what appears to be the same question. Part of this is a problem of resolution: different floors of a large building (to say nothing of an entire PXA) might have radically different calling behaviours and yet we must, of necessity, average the results across the entire area. So in some ways this is the return of the MAUP (see page 217) because we are converting between point and areal data, and are losing critical detail in the process.

But the problem is actually more complex than this because we are also smoothing out signals from a very noisy system, and the signal-to-noise relationship is extraordinarily difficult to understand. In Figure 8.3 we can see two exploratory eigenplace maps drawn using the information gleaned from the Synthetic and Analytical analyses (see pages 284 and 293). These plots were created by taking the PXAs assigned to two clusters with substantially differing levels of international calling from the earlier eigenplace analysis of significant locations—by which I mean Clusters #1 and #3 from the Synthetic Group #1 analysis (page 447), and Clusters #2 and #4 from the Analytical Group analysis (page 451)—and then examining how every other PXA in the GSE communicates with those two groups of PXAs. The question is this: what do these results mean?

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(a) More & Less International Financial Sites

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(b) More & Less International Analytical Sites

Figure 8.3: Eigenplace Analysis of Significant Locations

It would certainly be easy to develop a plausible account of these maps but, as the attentive reader will have readily noticed, we are dealing quite directly with questions of interpretation. Are patterns at this fine scale meaningful, or by drilling down to this detailed level are we actually now analysing only noise? In effect, the more fine-grained the analysis, the more likely we are to encounter the limits of such methods. This is the principal reason that I have worked with only the two largest types of flows—domestic and international—as the results may be harder to project down to the firm level, but they are less subject to the type of noise that *appears* to be affecting the results above.

An additional consideration for future research is whether or not an alternative clustering approach might yield superior results? The *k*-Means clustering is exclusive, such that an individual CLLI or PXA can be a member of one, and only one, cluster but it is clear from Figure 7.37 that this could be an important analytical issue. In contrast, a fuzzy *k*-Means clustering would allow the areal unit to fall between two or more clusters (*e.g.* that a particular exchange is 30% like Cluster #1 and 70% like Cluster #4), providing an indication of how sharp the spatial and behavioural distinctions within the data set truly are. Neural networks and Self Organising Maps (SOMs) offer still more categorisation options that could be pursued in subsequent research.

These are important considerations, but I nonetheless feel that the basic validity of the eigenplace for analysis at regional and national scales has been demonstrated. There are two areas in particular where it seems that the eigenplace method could be of use: first, the low latency of the eigenplaces (they could be calculated with as little as a week's worth of data) when compared with Census data offers substantial benefits to policy-makers trying to cope with cities and regions in transition; second, in countries where the data-collection infrastructure is weaker, an eigenplace analysis could help decision-makers understand where to focus their efforts. Moreover, as the contrast between the London and New York eigenplaces made clear (see page 419 for the more modest American analysis), in spite of the issues discussed above we have good reason to believe that the finer the spatial resolution, the finer the behavioural analysis that can be undertaken as a result. It is easy to imagine this type of analysis being useful to users whose objectives might range from targeted advertising or public awareness campaigns to infrastructure planning based on patterns of activity over time and space.

8.4 Current Trends & Coming Challenges

More broadly, the spatial and temporal dimensions of telecoms data make them peculiarly appropriate for tackling the series of challenges—modelled on those advanced by Graham (1997, p.106)—that I introduced in Introduction: the challenge of invisibility, and the challenges to theory, to analysis, and to concepts of time and place. However, to these four issues I now intend to add three more that are rooted in current social, economic, and technical trends. The intersection of changes in living preferences, labour markets, and technology—and particularly in our ability to access information and communicate from nearly anywhere on the planet, even while *en route* between locations—will mean new difficulties for planning that will require innovative approaches to transportation, the built environment, and governance.

Household Change

I have deliberately excluded any substantive analysis of household locational preferences from this work, but it is clear from Chapter 4 that the 'milieu preferences' of workers will have a profound impact on long-term travel and relocation patterns. The big picture is that both the workers and entrepreneurs are increasingly able to pursue high-amenity and high-dispersion strategies, and so it is hardly surprising that warm, sunny American cities outgrew their colder, wetter competitors in the second half of the 20th century (Glaeser, 2006). To the extent that households are able to meet their basic needs anywhere, then long-term migration should reflect their environmental and social preferences.

However, at the finer scale, two sub-trends are at work that may well lead to long-term 'mismatches' between household and employment location. The first sub-trend is the rise of dual-income households in which there are two heads-of-household and a consequent requirement to balance potentially conflicting locational needs. The second sub-trend is a rise in rates of home ownership which, when combined with decreasing job tenure and greater job specialisation, makes it *less* likely that an employee will live near their place of employment, or will be willing to relocate in order to do so (Surowiecki, 2008).

In principle, office relocation to edge-cities can improve accessibility for workers: according to Breheny, BT's 'Workstyle 2000' restructuring simultaneously reduced property costs for the firm and commute times for the staff by moving most of the firm's technical and research facilities to points around the M25 (1999, p.21). But in practice, reduced commute times for some may mean much longer orbital commutes for others if the new 'accessible' location is actually on the other side of the city: at what point does a worker sell the family home in order to reduce their own travel if it also means an increase in their partner's commute and the loss of access to a good school for the children?

Technology Change

The second major trend is ongoing technology change, and in particular its effect on the costs of mobility as set out in Chapter 2. Here, there are again two interrelated sub-trends that are worth considering: the first is the increasing pervasiveness of technology and the way that it enables greater flexibility in work and travel; the second is the potential for technology to substitute entirely for the need to travel. It will hardly surprise readers of this thesis to hear that the connection between these two issues is complex and is likely to have unanticipated consequences for both travel and sustainability.

In *A Day on the Trains, 2030*, Hall (2010b) imagines an integrated rail, bus, and bicycle network in which ticketing and alerting services are made available to users entirely electronically via smart-phones: goods and services can be purchased *en route*, reservations instantly changed if a traveller arrives early or late, and barriers and locks remain open unless a problem is reported. By increasing the ease with which people can travel, technology will lower the perceived cost of doing so. There is no reason to believe that we will need to wait until 2030 for this to become a reality: the near field communications systems required to enable barrier-less entry are already available in many phones, and real-time information systems for public and private transit are already widely deployed, what is lacking is the seamless integration.

A second aspect of this change is the overall impact of mobile technology on working habits: the combination of ongoing miniaturisation with increasingly sophisticated systems for sensory input will mean that workers become even less dependent on the office 'workspace'. Augmented reality overlays accessible on modern smart-phones are the near-term manifestation of this change, but the long-term direction is that people will be able to work in a wider variety of contexts: any horizontal surface might become a keyboard or input device, any vertical one a monitor, and all of this will be linked together by omnipresent networks that obviate the need to think in a conscious way about 'Internet access'. With no productivity penalty for working from the garden, the train, or the country, will there still be a need for the traditional office? And, in a related question, might deeper immersive virtual environments eventually replace the business meeting entirely?

8.5 Implications

Having set out what I believe to be the key trends to affect planning in the coming years, it is natural to turn to the likely implications of these trends for people and places. I have grouped these into three categories, elements of which have also been touched on at many points in this research: the interaction between communication and location, the effects of increasing mobility, and the resulting 'glocalisation' of cities.

Communications

Historically, it has been thought that we choose a location on the basis of time and money tradeoffs: the cost of travel was such that we would choose the 'best' mode of travel that we could afford. As a result, the value of an infrastructure project could be gauged principally through the time savings accruing to its users. This certainly seems a reasonable assumption: researchers have evidence to suggest that we spend no more time commuting now than our predecessors did fifty or a hundred years ago (Bretagnolle et al., 2001), we simply commute much further, faster and in greater comfort.

However, thanks to telecommunications, time spent travelling is no longer simply a 'dead time' that we would rationally seek to minimise. Graham (1997, p.120) noted that physical concentration acts "to overcome time constraints by minimising space constraints", while electronic concentration acts "to overcome space constraints by minimising time constraints." Mobile ICT makes this relationship even more complex. Figure 8.4, from Mitchell (2004, p.127), emphasises the way in which the insertion of mobility into the mix creates another set of relationships between place and non-place.

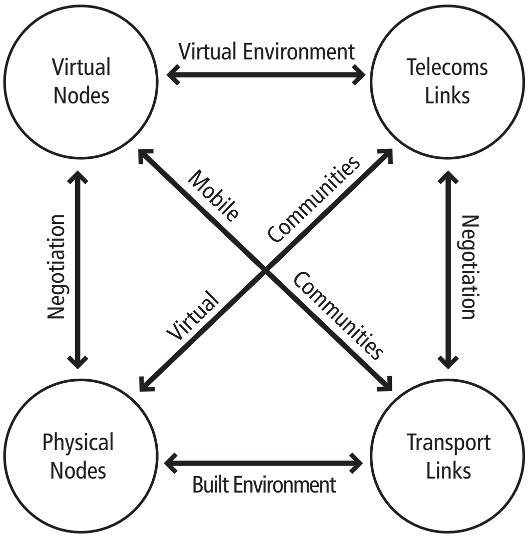


Figure 8.4: Physical & Virtual Structures and their Interrelationships (after Mitchell, 2004, p.127)

I have altered Mitchell's figure from the original for two reasons: first, the original unnecessarily emphasises telecoms links by placing them at the centre of the illustration, whereas I wish to emphasise the balance between these dimensions; and, second, the "Substitution? Complementarity?" labels between the two types of nodes and two types of links unnecessarily suggests a binary relationship, whereas the simpler concept of "Negotiation" emphasises the ongoing and adaptive process that I think this thesis has clearly established lies at the heart of the interaction. We continue to attach importance to both virtual *and* physical places, and seem to be using the one to augment, not replace, the other.

We can imagine that at some point in the not-too-distant future the expensive HD video conferencing systems now in place at some large companies might become widely available, affordable even by small firms and start-ups. However, as Graham (2005, p.99) has argued, we should not underestimate the importance of copresence to effective communication, not only because of the senses that cannot operate in virtual environments, but also because it has vital ritual or communal dimensions as well. Copresence signals importance and exclusivity of interaction (see Table 2.2 on page 57), as well as a level of involvement for which there will be no substitute for the foreseeable future.

Attending a local arts festival or joining colleagues or collaborators for an after-work drink at the pub is not an activity that can be mediated electronically. And while remote workers may come to attach less importance to such moments, it seems likely that they will nonetheless remain vital to many types of work. As Graham (2005, p.99) notes, "more information or bandwidth is not the same as more knowledge, understanding, or wisdom," and it is these latter aspects that are still best communicated face-to-face.

Mobility

The second issue raised by mobile communications is that the concomitant decrease in the relative cost of being 'out of the office' may allow people to live much further from the office, and that employee mobility may eventually substitute for permanent proximity. As the per-mile costs of travel have fallen, journeys—whether for work or for recreation—that might once have been rare because of the distance involved may become increasingly common: we are even seeing the emergence of unprecedented 'weekly commutes' between cities such as London and Amsterdam or Brussels using air and high-speed rail (HSR) infrastructure. So instead of the knowledge economy yielding sustainability savings through telecommuting, the situation may even worsen.

These emerging travel patterns are, of course, intimately connected to the trends discussed in the previous chapters. These long-distance 'commutes' are the province of highly-skilled knowledge workers who are in demand, and their skills are so specialised that it is rational for a firm to move them between countries as often as some of us move between cities. Moreover, the capabilities of long-range, upper-tier infrastructure mean that such workers now also have a much broader choice of household location: they can organise their own lives at the city and city-regional scale around amenity, around business networking, and around the needs of their 'better half' and their children.

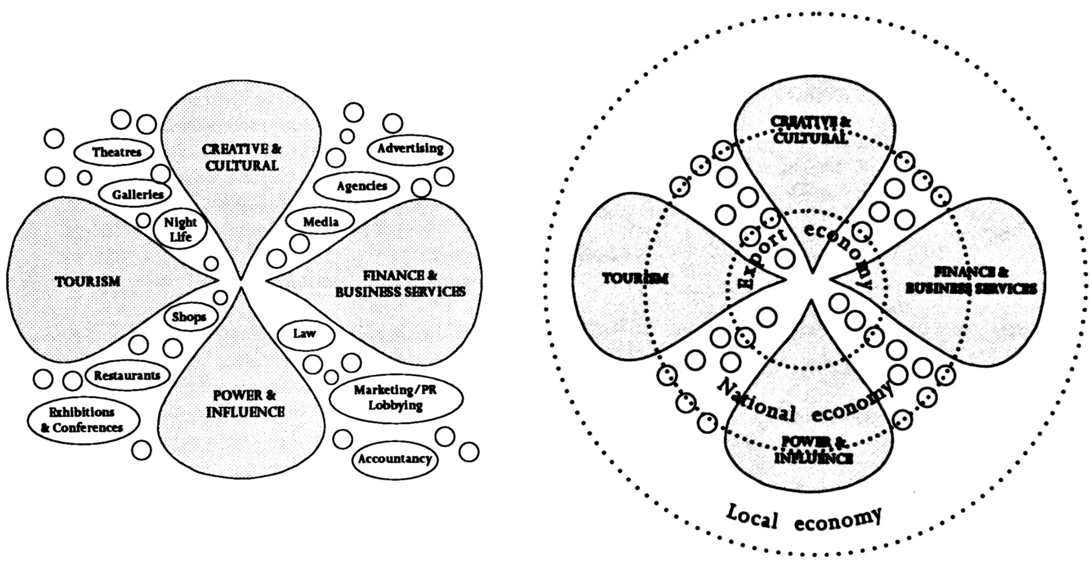
Sheller and Urry (2006) have called for a 'new mobilities paradigm' which posits that activities that occur while on the move need to be examined in interdependence to one another. Instead of taking 'demand' as a given and assigning it to the "product of discrete, simple categories such as commuting, leisure, or business" (2006, p.212), we need to think about places in which multiple needs can be met simultaneously. So while polycentricity may well be the 'wave of the future', we can expect to see as a result higher-than-ever rates of commuting between specialised centres along non-radial routes where public transit links tend to be weakest (Breheny, 1999, p.183). This is a planning issue not only because of increased infrastructure loadings and environmental impacts, but also because it implies that those without their own vehicle may be unable to fully participate in the knowledge economy (cf. Hall, 2009, p.815).

'Glocal' Cities

What does the intersection of household, technology, and employment change with communications and mobility improvements mean for the future of cities? The first implication is that the density of overlapping networks will remain a crucial developmental asset: particularly privileged sites, where transport, communications, social, and economic networks intersect, act as magnets and draw "wealth, power, culture, innovation, and people, innovative or not, to these places" (Castells, 2009, p.7). However, it would be a mistake to assume that such areas are *necessarily* urban since, as I have argued in Chapters 4 and 5, many of these dynamics now exist in more peripheral locations as well where the disbenefits of urban life are far away.

Where urban sites do have an advantage over less central ones is in the sheer diversity of networks that intersect there: Storper and Venables (2004, p.365) point out that the socioeconomic networks in 'buzz cities' span: "a) creative and cultural industries; b) finance and business services; c) science, technology, and research; d) power/influence (e.g. government, associations, NGOs, etc.)." The sub-centres, edge cities, and accessible rural areas that we considered in Chapter 7 all tend to demonstrate specialisation in only a few networks, whereas central London and New York suggest a diversity of sectors operating cheek-by-jowl in an area just a few miles across.

So the second implication is that workers operating in sectors where multi-lateral and cross-sectoral information and knowledge flows predominate will depend more on cities, whereas those with more bilateral or limited exchange requirements will not. More subtly, it is the industries operating in the interstices of the principal axes—at the seams between the financial and business, cultural, touristic, and power and influence domains—that constitute the critical 'ecology' that makes it so difficult for lesser conurbations to compete with cities like New York and London (see Figure 8.5a).



(a) Richness of Inter-Axis Activity (b) 4 Principal Axes of Global City Economies

Figure 8.5: Global/Local Urbanisations Economies (Llewelyn-Davies, UCL Bartlett School of Planning, and Comedia, 1996; reproduced with permission of the authors)

Our largest cities are also built on top of synergies spanning the global, national, and local scales (see Figure 8.5b). Again, the findings from Chapters 4 and 7 highlight the fact that there is not a disconnection between the global and the local but a dynamic, mutually-reinforcing relationship between them. In short, leading world cities are essentially 'glocal'. Of course, this is not a durable, unchanging structure: as we established in Chapter 3, new industries emerge from specialised demand in cities, stabilise, and move outwards in search of less expensive premises and staff. This dynamic only reinforces the global/local relationship between cities and their surrounding regions.

8.6 *Recommendations*

Given the broad thrust of this work and its focus on the dynamics in play rather than probable outcomes, it is difficult to generate only a few, simple recommendations for improving planning and plan-making in the face of challenges from ICT and mobility. Instead, I will here draw on the findings from the preceding chapters to make three deliberately provocative proposals with relevance to the main axes of contemporary planning: transportation, the built environment, and governance. It is not expected that these necessarily constitute realise-able policies, but that they act as departure points for consideration of how to meet pressing social, environmental, and economic challenges.

Transportation

The rising tide of carbon flowing from homes, businesses, and transport makes it clear that we need to manage emissions downwards, and radically too, but year-on-year the use of all forms of transport is growing. The critical point of failure, it seems to me, is that our public transport infrastructure is geared towards historic, radial location patterns—business in the CBD and households in the suburbs—when what is needed is a complementary infrastructure that somehow balances many of the flexibility advantages of private vehicles with the emissions characteristics and *en route* amenities of public transit, all geared to increasingly orbital commuting patterns.

I have pointed out that at the micro-level, technology-enabled flexibility can make public transit more competitive with private vehicles by streamlining access to information as well as to the service itself. Systems that improve the smoothness of point-to-point travel for commuters will obviously be an enormous asset here. But we can go beyond this to look at the types of synergies that might be offered at intermodal transfer points: in the *Better Rail Stations* report Green and Hall (2009) propose installing commonly-used services, such as post offices and dry cleaning shops, in a way that makes stations services, as well as transport, hubs. This approach recalls the intersection of multiple mobility networks and economic development that Bertolini and Dijst (2003) termed a ‘mobility environment’.

Whereas greater flexibility is unquestionably a positive for public transport use at the micro-level, at the macro-scale this is not necessarily true. Too much flexibility may actually undermine localised developmental incentives since, instead of encouraging the growth of only a few nodes through focussed demand, all nodes develop weakly and the existing structure remains largely unchanged. This dynamic seems particularly obvious in Britain’s air infrastructure: many airports across the North of England offer limited point-to-point connections (principally to holiday destinations), but none of them can come close to competing with the density of links at Heathrow and so it remains the preeminent node for global business in Britain.

So I would suggest *constraining* the growth of regional airports across Britain in favour of developing Manchester’s airport as a northern counterweight to Heathrow. Focussing demand on a single location should encourage specialisation and the provision of better services to more destinations. With the right supporting infrastructure—a 'Northern Crossrail' for instance—the airport could effectively serve Manchester, Leeds, and Liverpool, all of which have different mixes of potentially global-quality producers of research, ICT, and cultural outputs. Of course, such a development will not happen overnight, and so I would also propose strengthening the region's access to the GSE economy by accelerating the rollout of HSR to make it possible to reach Central London from Manchester in just 80 minutes by 2020 (GreenGauge 21, 2009).

Built Environment

Elsewhere in this thesis I have argued that the creativity that characterises knowledge work flows from social, economic, and institutional cultures, but it can clearly only really flourish when combined with a built environment appropriate to the individuals and firms generating that knowledge. The issue brings us back to knowledge bases, but it has to be seen in the context of a 'new urban form' that contains *many* sites of potential activity development (cf. Hall, 2003, p.145). Throughout this work I have been developing the thesis that each of these varied locations—primary, secondary, and tertiary cores, inner- and outer-edge cities, market towns, and on down to research parks—is likely to appeal to different types of firms at different points in their lifecycle of knowledge development and deployment. Many of these sites can be easily mapped on to the preferences summarised in Table 7.12 (page 320).

If symbolic knowledge operates principally through diversity and multilateral flows then this cannot be imposed through policy, but it can be undermined by it. Regeneration or development efforts that erase a textured, variegated local environment (however decrepit) in favour of 'modern' facilities with standard floor plans and 'new build' rents will gut its adaptability to new, innovative uses. A more creative approach might seek to increase the supply of informal spaces in which interaction can occur: Currid (2007) suggests employing tax policy to generate a new class of protected 'arts' tenant, but I tend to think that this would only make New York and London's housing situations even worse without necessarily improving the quality of cultural outputs. Instead, what I would suggest is that some zones already have the basic social infrastructure in place, and that we should ensure that planned regeneration, if any, is only conducted in a piecemeal way that preserves the wide range of facilities and rents upon which the cultural sector seems to thrive.

For the other knowledge bases the issues are quite different: the researchers and scientists generating analytical knowledge would seem to benefit from amenity-oriented sites together with straightforward access to those who might employ their outputs in practical contexts. In contrast, the engineers and consultants developing synthetic knowledge would seem to require access to a range of transport infrastructure at a variety of scales: regional, national, and international, depending on the activities of the consultancy. Both groups would seem to benefit from a mix of formal meeting spaces, and less formal encounter spaces, that are easily reached on local and medium-distance links, with more modest global connectivity. However, without the right kinds of complementary 'social infrastructure', I doubt that simply appending Regus-style managed office spaces and meeting rooms to rail stations would be a sufficiently attractive solution to reduce private vehicle mileage. Fully-developed facilities offering rail and bus interchange, together with car and bicycle parking, in an attractive setting offering a range of meeting contexts could well meet these groups' working and networking needs.

The broader interaction between home and work dynamics is complex, and I mean this here in the technical sense: the implication of true complexity is that there is no one 'solution' to how best to meet the needs of workers and entrepreneurs. Instead, we need to become better at searching for unique solutions and to developing them iteratively and responsively. In short, we need to be as creative in how we manage our cities as we are in how we develop new products and services (Hall, 2002a, pp.278–279). However, the current delivery system favours large developers and all but ensures that only a single or limited set of approaches will be employed.

Consequently, I would suggest that there is a need to systematically undermine the scale incentives that encourage cookie-cutter office, retail, and residential development. Simply by virtue of their closer connection to local communities and their potentially large numbers, smaller builders are more likely to pursue unconventional solutions that are nonetheless responsive to the individual context in terms of form and substance (*e.g.* affordability, accessibility, household sizes, and so forth). Procurement policies should favour adaptive approaches since, although some of them may fail spectacularly, others may offer profoundly effective responses to the major societal challenges that we face.

Governance

By 2030 the majority of people on every continent will live in 'urban environments' (Castells, 2009, p.2), but many of them will live in largely unplanned and unconnected extensions—slums and suburbs of various descriptions—created as a response to the pressing need for access to the opportunities and services of the core cities and their complementary sub-centres. The key governance challenge therefore is that the increasingly polycentric region does not relate in any coherent way to the traditional boundaries of historical administrative entities[1] and that there "are nuclei of different sizes and functional importance distributed along a vast expanse of territory following transportation lines" (2009, p.3).

As a result of these changes, policy faces a critical test: how to reconcile the need to actively manage individual mobility for environmental reasons with the fact that it is also closely correlated with economic

[1] See, for instance, Jacobs (cf. 1984, pp.109–119) for a discussion of the problems faced by the Tennessee Valley Authority, an administrative region without an urban economic heart.

opportunity? For instance, the European Spatial Development Perspective (ESDP) is largely premised on the desirability, achievability, and sustainability of spreading economic growth to less developed areas across Europe using transportation and telecommunications networks. There is a clear 'network logic' which holds that after 'plugging in' these regions a more balanced pattern of development will naturally follow. The scale of spending on integrationist projects is enormous—the TEN-T priority transportation schemes alone involve more than € 20 billion in public funds, and over € 300 billion in private money.

I have tried to set out ways of understanding and analysing infrastructure, firms, and knowledge in ways that might help policy-makers to get to grips with the likely impact of such spending on urban and regional development. However, perhaps the deepest failings of much of contemporary governance are its simple-mindedness and short-termism: we all—planners, policy-makers, and the public—seem to be addicted to easy answers and immediate returns when the entire history of urban develoment points in the opposite direction: towards slow, careful, plodding work, and rare moments of synergy emerging from complex interactions between largely unforeseen forces.

There will never be a simple answer to how cities and regions can become the next cultural mecca (cf. critique in MacGillis, 2010), or technological dynamo (cf. critique in O'Mara, 2010). However, by working incrementally and adaptively in the short-term, and being willing to wait decades for the long-term rewards to emerge—the 20 or 30 years of Japan, not the standard 10 of the West (Castells and Hall, 1994, p.75)—it seems to me that we could significantly improve the probable outcomes of our efforts. In spite of my recommendations above, if there is one point that bears reiteration from the Introduction, it is that infrastructure interconnectivity makes instrumental approaches to their development uncertain at best (Innes, 2005, p.60), and that planning and policy are best approached with an open mind, a degree of humility, and a great deal of creativity.

8.7 Final Thought

There is no doubt that some types of technological change stimulate wider social change: the passenger jet gave rise to the jet-age, the jet-set, and, of course, to jet-lag (BBC Four, 2009a). Thanks to the 'mobilisation' of ICT, we are in the midst of another such transformation, and change in the ways in which we experience the world is necessarily implicated in equally important shifts in the way that we perceive ourselves and our environment. Townsend and Moss (2008, p.28) suggest that early aerial photography marked a 'turning point' in our understanding of the city, and the mapping of telecommunications flows and of social networks has the potential do the same for us today. As Dodge and Kitchin (2001, p.4) put it in connection with their review of visualisations of 'cyberspace': "A key question thus to ask to what extent…does a map or spatialisation change the way that we think…" In bringing one part of the 'space of flows' into focus—and in thinking not only about the space, but also about what constitutes the flows—it is my hope that this work has contributed to changing the way that we think about the place of telecommunications in the ongoing evolution of urban form and function.

9
Appendix A: Aggregate Spatial & Temporal Calling Data

9.1 Global, Regional & Domestic Calling

Global Calling

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(a) To and from New York City

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(b) To and from London

Figure 9.1: International Call Volumes

Figure 9.1a maps out the absolute flows between New York City and the rest of the world at the country-scale, while Figure 9.2 shows how this activity is distributed following normalisation by each country's population. The second map highlights distinctive groupings in New York's interactions: Central America and the Caribbean are particularly prominent, as are the Philippines and islands of the South Pacific such as American Samoa; and in the Middle East/Africa there are clusters around Liberia and Kuwait. Smaller, but no less significant on a *per capita* basis, are flows to Israel, Italy and, rather surprisingly, Gibraltar[1]. Broadly, this distribution of minutes persists, regardless of whether we examine inbound data, bidirectional flows, or even break down the call volumes by platform.

[1] This may be a product of its small population, but it is nonetheless surprising.

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Figure 9.2: Normalised Call Volumes to and from New York City

New York's strongest bidirectional (*i. e.* total flow in both directions) link is with Canada, followed by the Dominican Republic (87% of Canadian minutes), the United Kingdom (76%), and Mexico (61%). After this, there is a rapid drop-off, with Guatemala the next most-called country at barely 32% of Canada's talk-time. Since Canada shares the same telephone addressing system, we can be fairly certain that Toronto is the most-talked to city in Canada (35% of Canadian minutes), followed by Montreal (13% of minutes). Vancouver, Ottawa/Hull, and Calgary trail far behind, accounting for roughly 3% of calls and 3% of minutes each, which is somewhat surprising given that Ottawa is the nation's administrative capital. More cautiously, we can advance the notion that Santo Domingo is the most-called city overall (nearly twice the minutes of Toronto), followed by London (107% of Toronto's total). Weighting the results by recent migration flows to New York shows a few unusually strong international links, but the results are broadly consistent with this map (see Figure 9.3 on page 342).

More simplistic readings of 'world cities' literature might lead some readers to expect that communications flows to and from New York would be organised around the activities of the financial markets, and that calls to London and, to a lesser extent, Tokyo would dominate, followed by a second tier of calling to and from the 'home' countries of the migrants working at the 'less-skilled' end of New York's economy. Instead, what we find is that two relatively small countries (population-wise) occupy the top two slots in any list of New York's global communications patterns, and that they are countries that not only supply large numbers of migrants (from both ends of the skills base), but also have strong economic and cultural links. In other words, no one process dominates these informational flows, and the top ten list of New York's communications partners contains: Canada, the Dominican Republic, the United Kingdom, Mexico, Guatemala, Germany, India, Ecuador, France, and Jamaica. Canada's total bidirectional minutes are roughly four-and-a-half times those for Jamaica.

Emphasising the combined influence of economic and factors, Figure 9.3 demonstrates the impossibility of determining the appropriate frame of reference for measuring an 'expected' level of interaction between a given city and any other arbitrarily selected place at this scale. Here, we are assuming that it is the movement of people over time that is the appropriate metric, and not of money or goods, both of which can only be measured for the New York and New Jersey Port Authority as a whole (The Weissman Center for International Business, 2009)[2]. Recent immigrant data is taken from *Immigrants Admitted by Class of Admission and Country of Birth* available at New York City Department of City Planning (2000); country of origin data taken from *QT-P15: Region and Country or Area of Birth of the Foreign-Born Population: 2000* (U. S. Census Bureau, 2000). However, we have not yet accounted for the impact of distance and time zones on call volumes, and it might be expected that Asia would show fewer calls and minutes simply by virtue of the difference in times of day.

[2] Note that per person results for Monaco and the Vatican City are based on the total French and Italian population figures since the relevant populations seem impossibly small to generate this volume of telecommunications. Additional support for this approach comes from the fact that both city states share(d) the international dialling code of their surrounding nation state. Consequently, although this data is shown for consistency, it should probably be ignored.

I have used two sources of migration data to form a basis for comparison of international calling activity. Figure 9.3a uses the Country of Birth reported in the 2000 Census for the entire New York City population, whereas Figure 9.3b uses the Country of Birth figures only for Immigrants admitted to New York in the 1990–1999 period; the latter might be expected to have stronger ties to their country of origin. The results show that the particularly strong relationship between New York City and Canada, and between NYC and the United Kingdom is retained even after this transformation. If anything, it is accentuated. But some other interesting 'spikes' are visible in this cumulative data: Australia is particularly evident, which is surprising given the time difference, and Spain and Germany also put in an appearance. The prominence of Switzerland seems *likely* to be connected to the activities of 'supra-national institutions', particularly the United Nations in Geneva (Sassen, 2008, p.11).

Figure 9.3: Per Capita Wireline Calling to/from New York City

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(a) All Immigrants

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(b) Recent Immigrants

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Figure 9.4: International Calling Cycles to/from New York City

In the following figure I have separately normalised the sum total of calls and minutes for the entire month between New York City and the appropriate state against the largest single domestic value observed in the data set. So in the case of Figure 9.5, domestic calls have been normalised against the monthly total calls to California, while domestic minutes have been normalised against the monthly total time spent on the phone with Florida. In Figure 9.5, calls and minutes have been divided by each state's population (U. S. Census Bureau, 2008) and then normalised against the peak per person value found for Washington, D.C.

Several features of this plot are quite striking: the first is the decay in terms of both calls and minutes without taking population into account; the second is that there is a small number of states where the relationship between calls and minutes is clearly and substantively different from that of the rest of the country. In the cases of Florida, North Carolina, Colorado, and Puerto Rico the number of outbound minutes is substantially higher than we'd expect based on the corresponding number of minutes. In other words, it seems that people spend more time on the phone with people in these states and territories.

Figure 9.5: Total Normalised Domestic Telecoms Flows

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However, switching to a *per capita* value radically changes our view of the data: the significance of Washington, D.C. can only be understood as a function of its administrative role and of the importance of the relationship between the firms operating in New York City and the regulatory and legislative decisions made in D.C. The prominence of New Jersey and Connecticut can almost certainly be attributed to their role in the functioning of the larger New York-centred Mega City Region (MCR).

Regional & Domestic Calling

Turning now to the domestic scale, Figure 9.7 shows the total volume of minutes, scaled against the largest flow, for the three cities considered in the Analysis. Because we are not dividing by the number of phones in each city, London is always the predominant flow (except, obviously in the case of calls to and from London itself). This figure usefully highlights the extent to which London truly does dominate domestic communications; however, it also brings into relief the importance of Birmingham, which was largely lost from the normalised analysis undertaken in Chapter 7. More targeted work would be required to understand whether this is a dual business/residential dynamic, or if one of these is the dominant driver of interaction.

We can also examine New York's links to the rest of America at the state and inter-urban scales. Figure 9.8 shows the strength of New York City's links with other states, especially along the Eastern Seaboard.

Figure 9.6: Outbound Private Branch Call Volumes from New York

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Although some of these connections are much as we would expect, encompassing the Tri-State area presupposed to constitute the New York City Mega-City Region (MCR), as well as other major regional economies such as Illinois, Texas, and California. It is rather more surprising, however, to see that the maximum telecommunications flow across land line and mobile circuits is with the southern state of Florida. And note too the magnitude of flows to states such as Arizona and Colorado together with the *lack* of interaction with the Northwestern U.S. and Mid-West—although these are states with comparatively small populations, the links are tiny indeed—and the relatively modest level of interaction with California given its large population and economy.

Normalising by the number of people in each state rather dramatically changes the ranking of domestic flows to and from New York: for total flows, Washington, D.C. has nearly twice the *per capita* volume of the next most-called state of Connecticut. Obviously, this dynamic can only be understood in the context of Washington's role as a regulatory and administrative centre for America, but it also subtly highlights one issue with our being unable to combine traffic from several operators: this operator has important contracts to supply services to government offices in D.C. and so a great deal of business-to-government traffic will be carried from end-to-end, possibly skewing the results towards over-representation. At the urban scale, the dominant links for bidirectional traffic are, in order of importance, Miami, Atlanta, Los Angeles, Denver, Chicago, Washington D.C., Orlando, and Houston.

The importance of Los Angeles at the inter-urban scale goes some

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Figure 9.7: Total Call Volumes to/from London, Manchester & Stoke-on-Trent

way to correcting the perception generated by California's lower level of interaction in Figure 9.8. But in the broader picture, these connections seem to fall into two categories: business-dominated flows between NYC and Atlanta, L.A., Denver, Chicago, D.C., and Houston, and socially-dominated flows with places like Orlando where many 'snow bird' New Yorkers retire or own property. In fact, of the top twenty-five most talked-with cities, seven are in Florida, with Tampa, Jacksonville, Fort Lauderdale, West Palm Beach, and North Dade rounding out the state's representation in New York's communications flows. The importance of Miami in this table—which is not generally predicted by the world cities literature—seems connected to the confluence of several trends: retirement migration by 'snow birds'; the existence of large immigrant communities from Central America; and Miami's position as gateway to business in Central and South America.

Figure 9.8: Percent of Maximum Wireline & Wireless Volumes to and from New York

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9.2 Temporal Aspects

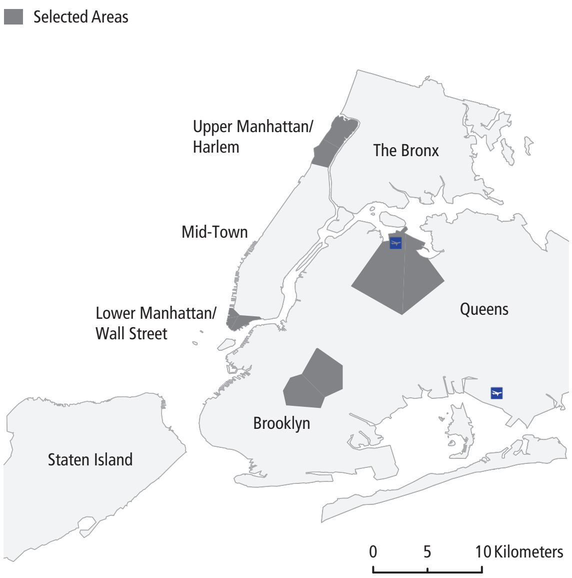

Figure 9.9: Location of Selected New York City Neighbourhoods

International volumes to and from 'Upper Manhattan' differ from those elsewhere: we can determine from Figures 10.51 and 10.4 (pages 412 and 362) that this is a strongly Hispanic/Dominican neighbourhood, and the underlying data confirms that the timing of this surge in call volumes is connected to calls to Central and South America (the Dominican Republic, Mexico, and Ecuador are ranked 1st, 2nd and 4th, respectively).

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(a) New York

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(b) London

Figure 9.10: Volume of International Calls

Figure 9.11: Domestic Calling (London)

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(a) Central London (Calls)

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(b) Croydon (Calls)

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(c) Ealing (Calls)

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(d) North London (Calls)

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(e) Central London (Volume)

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(f) Croydon (Volume)

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(g) Ealing (Volume)

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(h) North London (Volume)

Figure 9.12: Domestic Calling (NYC)

Suppressed from electronic copy at request of research partner

(a) Brooklyn (Calls)

Suppressed from electronic copy at request of research partner

(b) Lower Manhattan (Calls)

Suppressed from electronic copy at request of research partner

(c) Queens (Calls)

Suppressed from electronic copy at request of research partner

(d) Upper Manhattan (Calls)

Suppressed from electronic copy at request of research partner

(e) Brooklyn (Volume)

Suppressed from electronic copy at request of research partner

(f) Lower Manhattan (Volume)

Suppressed from electronic copy at request of research partner

(g) Queens (Volume)

Suppressed from electronic copy at request of research partner

(h) Upper Manhattan (Volume)

Figure 9.13: International Calling (London)

Suppressed from electronic copy at request of research partner

(a) Central London (Calls)

Suppressed from electronic copy at request of research partner

(b) Croydon (Calls)

Suppressed from electronic copy at request of research partner

(c) Ealing (Calls)

Suppressed from electronic copy at request of research partner

(d) North London (Calls)

Suppressed from electronic copy at request of research partner

(e) Central London (Volume)

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(f) Croydon (Volume)

Suppressed from electronic copy at request of research partner

(g) Ealing (Volume)

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(h) North London (Volume)

Figure 9.14: International Calling (NYC)

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Suppressed from electronic copy at request of research partner

(a) Brooklyn (Calls)

(b) Lower Manhattan (Calls)

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Suppressed from electronic copy at request of research partner

(c) Queens (Calls)

(d) Upper Manhattan (Calls)

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Suppressed from electronic copy at request of research partner

(e) Brooklyn (Volume)

(f) Lower Manhattan (Volume)

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Suppressed from electronic copy at request of research partner

(g) Queens (Volume)

(h) Upper Manhattan (Volume)

Figure 9.15: Mobile Calling (NYC)

Suppressed from electronic copy at request of research partner

(a) Brooklyn (Calls)

Suppressed from electronic copy at request of research partner

(b) Lower Manhattan (Calls)

Suppressed from electronic copy at request of research partner

(c) Queens (Calls)

Suppressed from electronic copy at request of research partner

(d) Upper Manhattan (Calls)

Suppressed from electronic copy at request of research partner

(e) Brooklyn (Volume)

Suppressed from electronic copy at request of research partner

(f) Lower Manhattan (Volume)

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(g) Queens (Volume)

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(h) Upper Manhattan (Volume)

Call Patterns at the Borough Level

Spatial Patterns: The lq and slq analyses for New York shown on page 359 suggest that businesses—and especially advanced business services—are highly concentrated in Manhattan, with relatively less activity in the surrounding four boroughs. Figure 9.16 shows the monthly total of calls and minutes between a borough and eight global regions. The figure clearly shows that, over the course of a month, significant differences accumulate in the calling patterns and volumes of each borough. To avoid the release of sensitive information about call volumes, the data here has been converted to a logarithmic scale and then normalised against the maximum borough/region value. This transformation also helps us to control for the fact that calling within North America (here taken to be the United States, Canada, and Mexico) is in some cases more than 35 times greater than calling abroad.

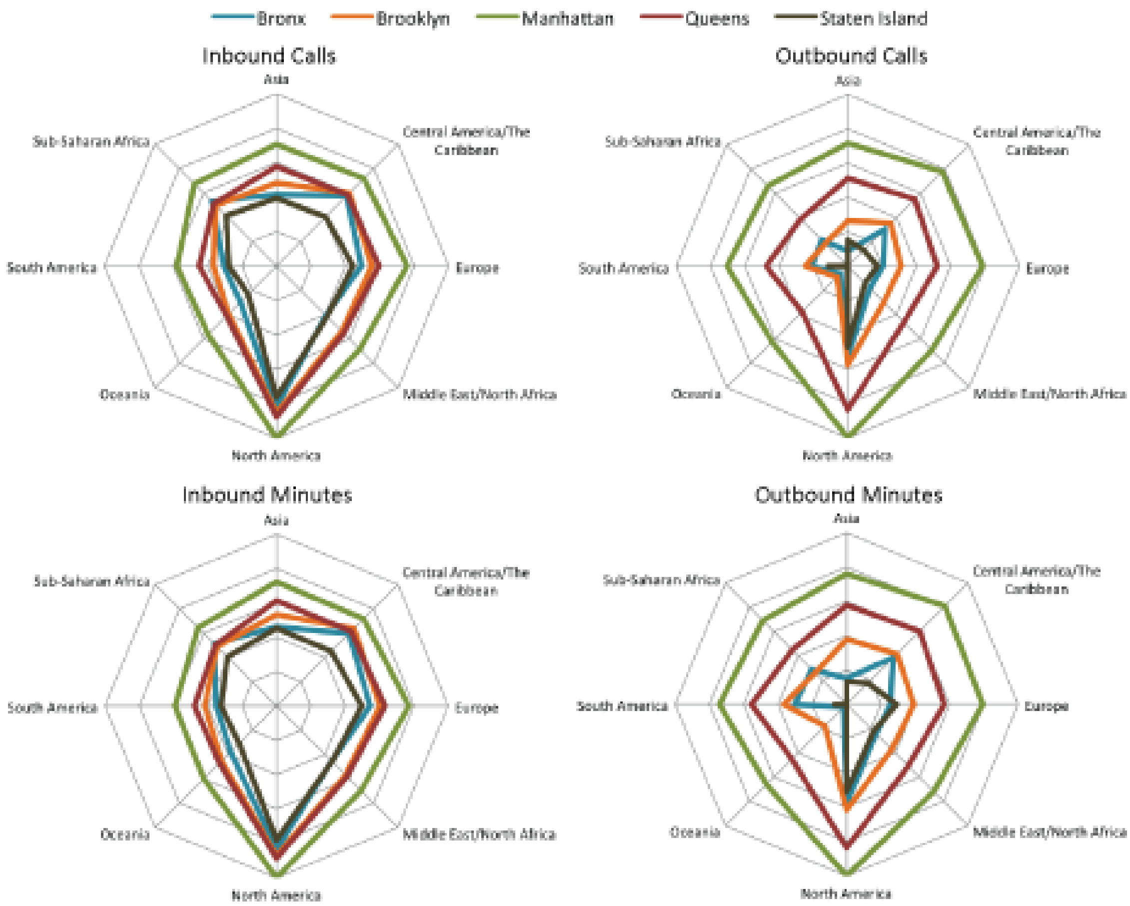


Figure 9.16: Log Normalised Wireless Calls by Global Region and Borough

We can combine these high-level observations with some details drawn from the regional axes in the plots. For wireless calling there is much wide variation between boroughs, with almost no outbound calling to Oceania or Sub-Saharan Africa from Staten Island, the Bronx, and Brooklyn. In contrast, there is a significant level of calling from both Europe and Central America/The Caribbean in to all five boroughs.

Timing of Calls at Borough Level: Logically, the timing of calls to and from each of the boroughs will also provide us with important information about local activity, be it residential or business-related. Figure 9.17 organises the data to make it clear that there are several distinct factors coming into play for domestic calling: a remarkably consistent pattern of wireline usage that strongly suggests the daily business cycle; and wireless calling that closely tracks wireline usage but takes a drastically different turn after 5 p.m. In contrast, and perhaps because of the range of time zones covered, international calling is much more difficult to interpret: note primarily that wireline and wireless calling from Manhattan peak earlier in the day than calls from the other five boroughs, and that wireline calling from the four outer boroughs remains strong until late in evening.

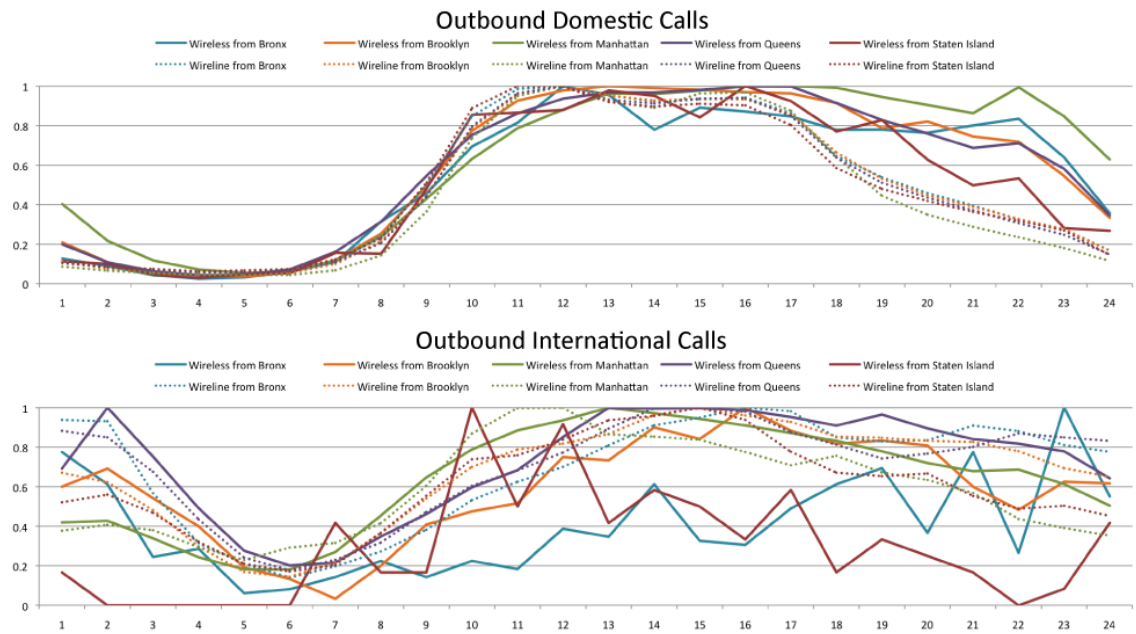


Figure 9.17: Domestic & International Calling by Platform

The high volume of international wireline calling to and from Queens and Manhattan shown in Figure 9.18 provide particularly illustrative figures. Here, outbound calls to each region have been normalised against the peak number of calls or minutes to that region during the day; this serves to emphasise when the majority of calls are placed and to examine whether there are material differences between the way that calls originate in Manhattan and in one of the predominantly residential boroughs.

It should be quite clear from the shape of the two figures that the difference in calling volumes between even the two largest boroughs is enormous. Furthermore, there are some quite striking differences between the two plots in terms of timing: relatively speaking, there is less call activity originating in Manhattan after 7 p.m. then in the

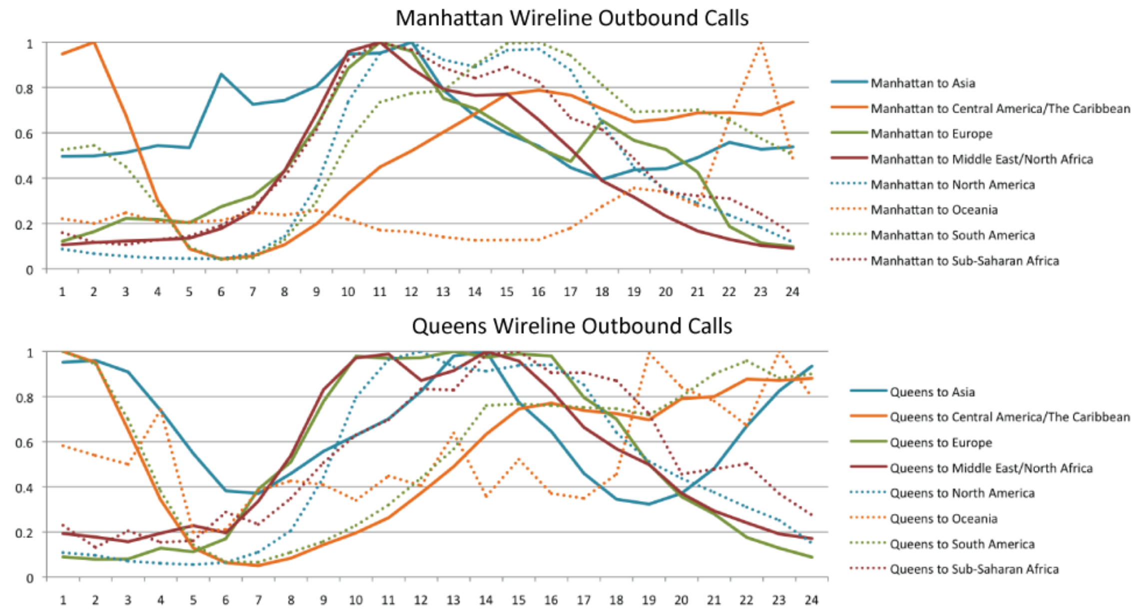


Figure 9.18: Wireline Calls by Time of Day and Region

period between 9 a.m. and 5 p.m., and with the notable exception of calls to Asia, Manhattan also shows a broad tendency towards rapidly rising call frequencies to all areas of the world between 7 a.m. and 10 a.m.

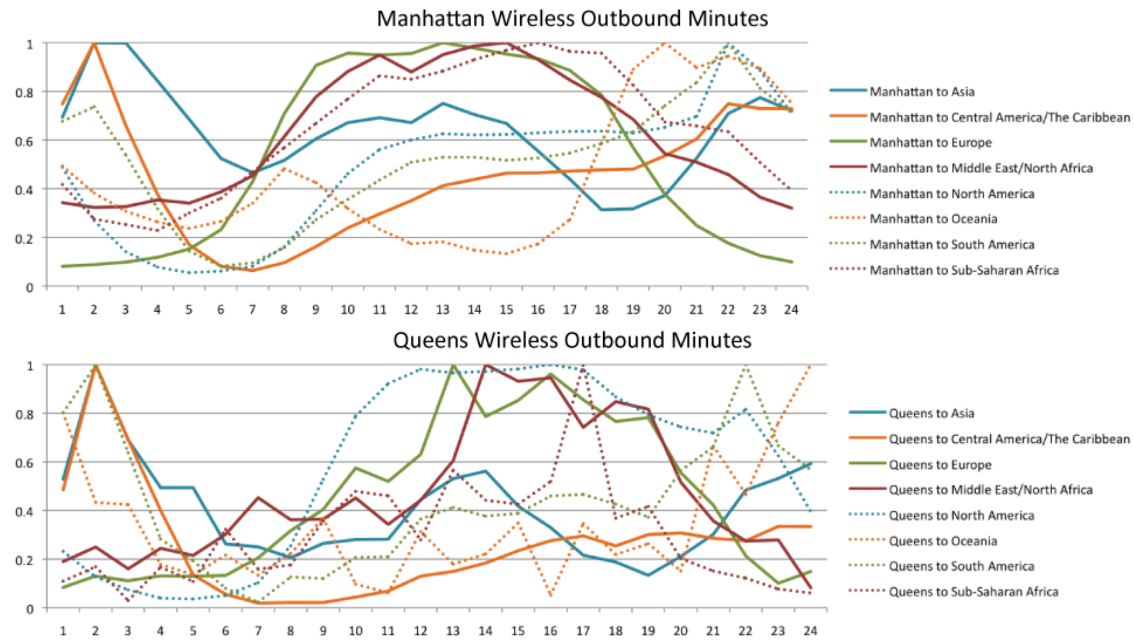


Figure 9.19: Wireless Minutes by Time of Day and Region

Calls to the rest of North America show the classic double-peaked usage shape observed during previous research in Rome (Reades et al., 2007). The rise in calls to Europe, the Middle East, and Sub-Saharan Africa is offset by about an hour from the uptick in calls to South America, Central America/The Caribbean, and the rest of North

America. Intriguingly, while calls and minutes tend to have similar peaks and lulls, there are one or two significant differences: there is a large secondary peak in the duration of calls to Oceania from Manhattan between 6 a.m. and 9 a.m., while calls to Central America and The Caribbean remain quite short throughout the day.

In wireless calling we see some significant differences in terms of overall usage: higher levels of usage quite late into the evening, and much less of the 'double-peak' observed for landline calling. Perhaps the most intriguing aspect of these two plots is that the duration and number of calls to Asia appears to have two distinct peaks in both calls and minutes that are quite widely spread: one seems to fall late in the morning, with a second, higher peak occurring after midnight. For now we can only speculate that this might actually reflect two types of activity: business-related calls during the day, and personal calls late at night.

10
Appendix B: Location & Telecommunications Quotients

10.1 Location Quotients

New York City

Although the broad outline of New York City's socioeconomic structure is undoubtedly well-known to most readers (for those uncertain of areas being discussed, please refer to Figure 7.9 on page 265)—global finance on Wall Street in Lower Manhattan, significant numbers of multinationals and retail bank headquarters in Mid-Town, and so on—the use of wire centres as an analytical unit obviously affects the way in which we can get to grips with the distribution of firms and households. Generally speaking, the largest numbers of residents can be found in the Bronx and in Queens, which may have as many as two hundred to three hundred thousand residents per wire centre, but the densities are significantly higher in Manhattan where they reach nearly 45,000 people/km^2.

Significantly, the residential population in Manhattan tends to be concentrated in the northern half of Manhattan, with the notable exception of the Lower East Side/Chinatown. This distribution holds even when we take density into account, and contrasts with the spatial distribution of employees, the majority of whom can be found in Lower Manhattan and Mid-Town, with slightly lower concentrations across the Brooklyn and Washington Bridges. Figure 10.1 shows where employment is particularly highly-concentrated within the five boroughs, and although the use of a ratio masks important employment centres in Queens (between the Mid-Town Tunnel and Queensborough Bridge) and Brooklyn (the 'Downtown Brooklyn' area around Borough Hall), it helps to highlight areas where we might reasonably expect business calling to predominate.

As discussed in Chapter 6 (see page 237), we can use the Localised and Standardised Location Quotients (LLQ and SLQ) to move away from the selection of arbitrary LQ thresholds to identify important business clusters. So if the data fits a normal distribution (whether normal or lognormal) then we can use the standard deviation to help us identify particularly important wire centres and exchanges. The results of the

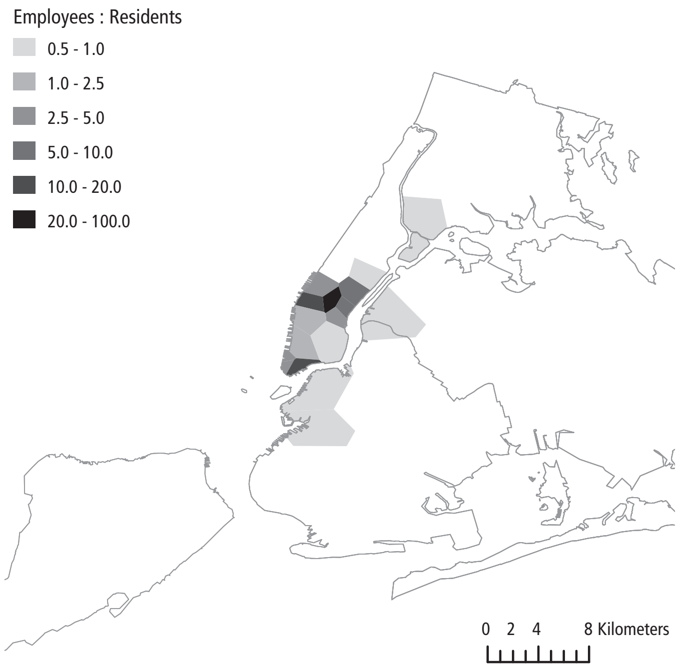


Figure 10.1: Ratio of Employment To Population by Wire Centre

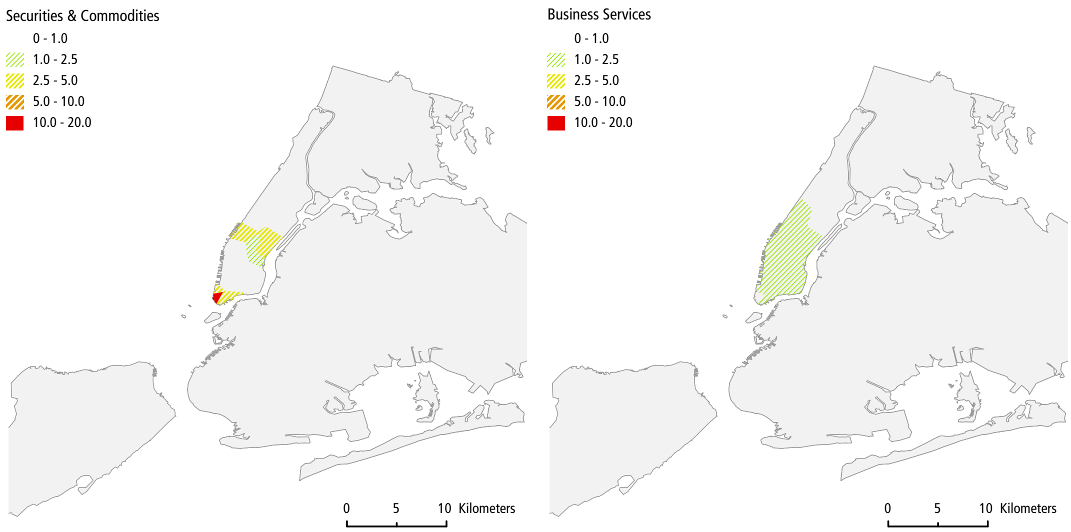
Lilliefors test for industries in New York—performed with a significance of 0.1 (*i. e.* 10%)—show that after a logarithmic transform only *some* of the major employment categories can be made to fall within a plausibly normal distribution (see Table 10.1[1]). The p-value is an overall measure of how likely it is that the data was drawn from a normal distribution, but we determine whether or not a sector is normally-distributed by comparing the Kolmogorov-Smirnov (KS) Statistic to the Critical Value: if the KS Statistic is greater than the Critical Value, then we *reject* the 'null hypothesis' that the data is drawn from a normal distribution, if less then we assume that the data follows a normal distribution.

[1] Non-normally distributed industries were: Retail, FIRE (Finance, Insurance & Real Estate combined), Banking, Securities, Personal Services, Business Producer Services (BPS), and Legal.

Group/SIC Code	p-value	KS Statistic	Critical Value
Insurance	$2.863429e^{-1}$	$8.412393e^{-2}$	$1.000031e^{-1}$
Real Estate	$5.000000e^{-1}$	$6.267091e^{-2}$	$1.000031e^{-1}$
Services	$2.833993e^{-1}$	$8.430268e^{-2}$	$1.000031e^{-1}$
Hotels	$2.166778e^{-1}$	$9.007839e^{-2}$	$1.015018e^{-1}$
Film	$5.000000e^{-1}$	$6.393906e^{-2}$	$1.000031e^{-1}$
Manufacturing	$3.739869e^{-1}$	$7.928490e^{-2}$	$1.000031e^{-1}$
Utilities	$1.048264e^{-1}$	$9.936389e^{-2}$	$1.000031e^{-1}$
Wholesale	$4.401926e^{-1}$	$7.610477e^{-2}$	$1.000031e^{-1}$

Table 10.1: Lognormal Industries in New York City

In part, the small number of normally-distributed sectors may be the result of low sample sizes: there are just 66 wire centres within NYC, many of which have little to no employment in the sectors that are of the most interest. For those sectors which *do* show a normal distribution, we can use the standard deviation to determine whether or not the concentration of employment in sector i in area A is statistically significant relative to the region R. When we have calculated the mean and standard deviation, then the *z*-score is simply a measure of how many deviations an area's value is above *or* below the distribution's mean. O'Donoghue and Gleave argued that *z*-scores beyond ±1.96 should be considered statistically-significant outliers since this is equivalent to the 5% level of significance commonly used in social science research (2004, p.422).



(a) NYC LQs Securities & Commodities Brokers

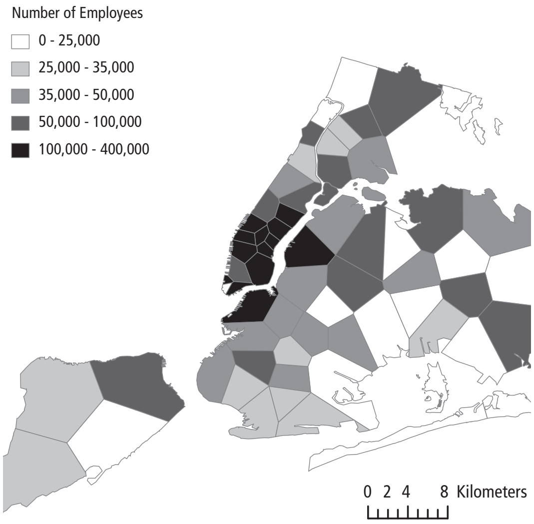
(b) NYC LQs Business Services

Figure 10.2: NYC LQ Results

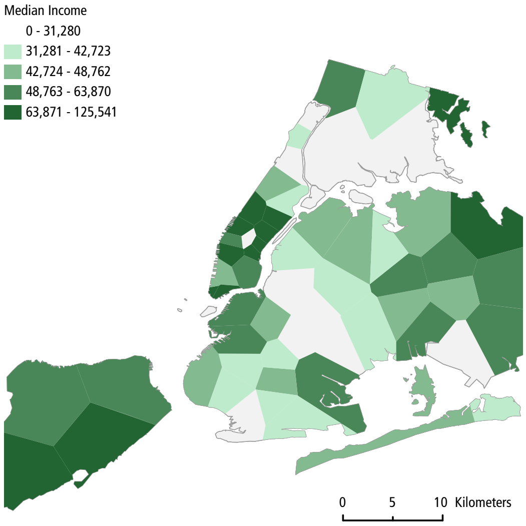
In the cases of both New York and London, after standardising the LQs many industries no longer meet the ±1.96 threshold. Since this sets a very high threshold for significance (and the issue is only peripherally relevant to our exploration of telecommunications activity anyway) I elected to show *two* thresholds when the distribution was found to be normal: ±1.5 (13% confidence interval) and ±2.5 (1% confidence interval) to give a sense of the range of geographical clustering. In cases where the distribution was not normal, I selected an arbitrary, but consistent, range based on the maximum LQ observed for all sectors within the study area.

Returning our focus to NYC, we find that two of the sectors of most interest to us—the trading activities associated with Wall Street, and the business services activity in support of other firms—are not normally-distributed. Trading activity is highly-concentrated at the southern tip of Manhattan, largely on Wall Street, but important concentrations have also emerged in Mid-Town in the area near Grand Central Station, Times Square, and Columbus Circle (see Figure 10.2). Legal Services (see Figure 10.5 on page 363) has largely followed finance, but in contrast Business Services Providers (BPS[2]) display greater dispersion, with low concentrations (LQs of 1.0–2.5) across all of Lower Manhattan (see Figure 10.2b). These results suggest that the data from New York City may simply not extend far enough from Manhattan to offer up a meaningful structural interpretation of industry preferences.

[2] Unfortunately, because of the way that the New York industrial data was calculated it was impossible to directly compare the Business Services group from New York with the APS group from London and the GSE.

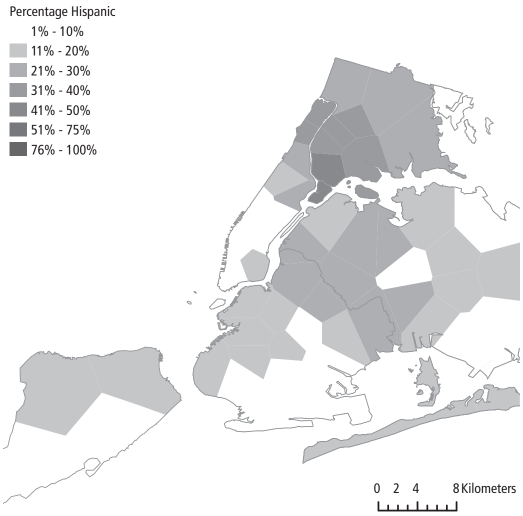


(a) Concentration of Employment by Wire Centre

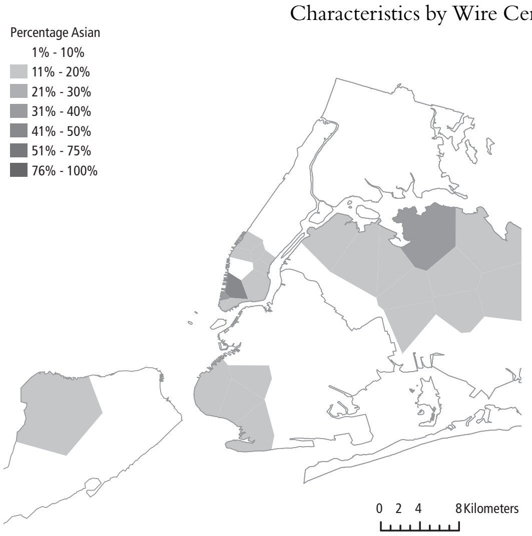


(b) Concentration of Income by Wire Centre

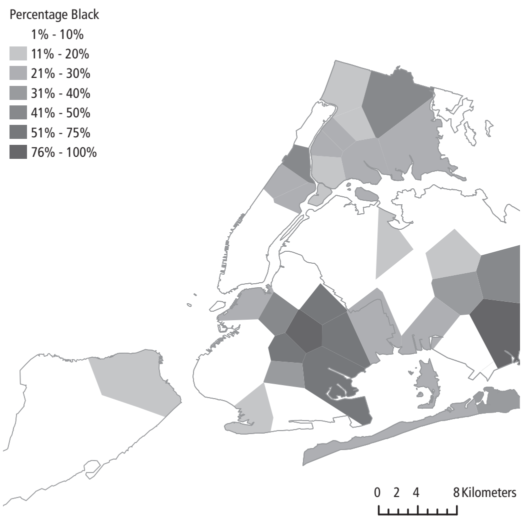
Figure 10.3: Sociodemographic Characteristics by Wire Centre



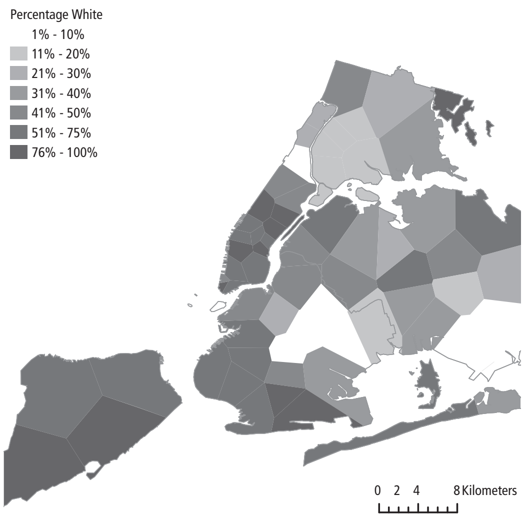
(a) Hispanic



(b) Asian

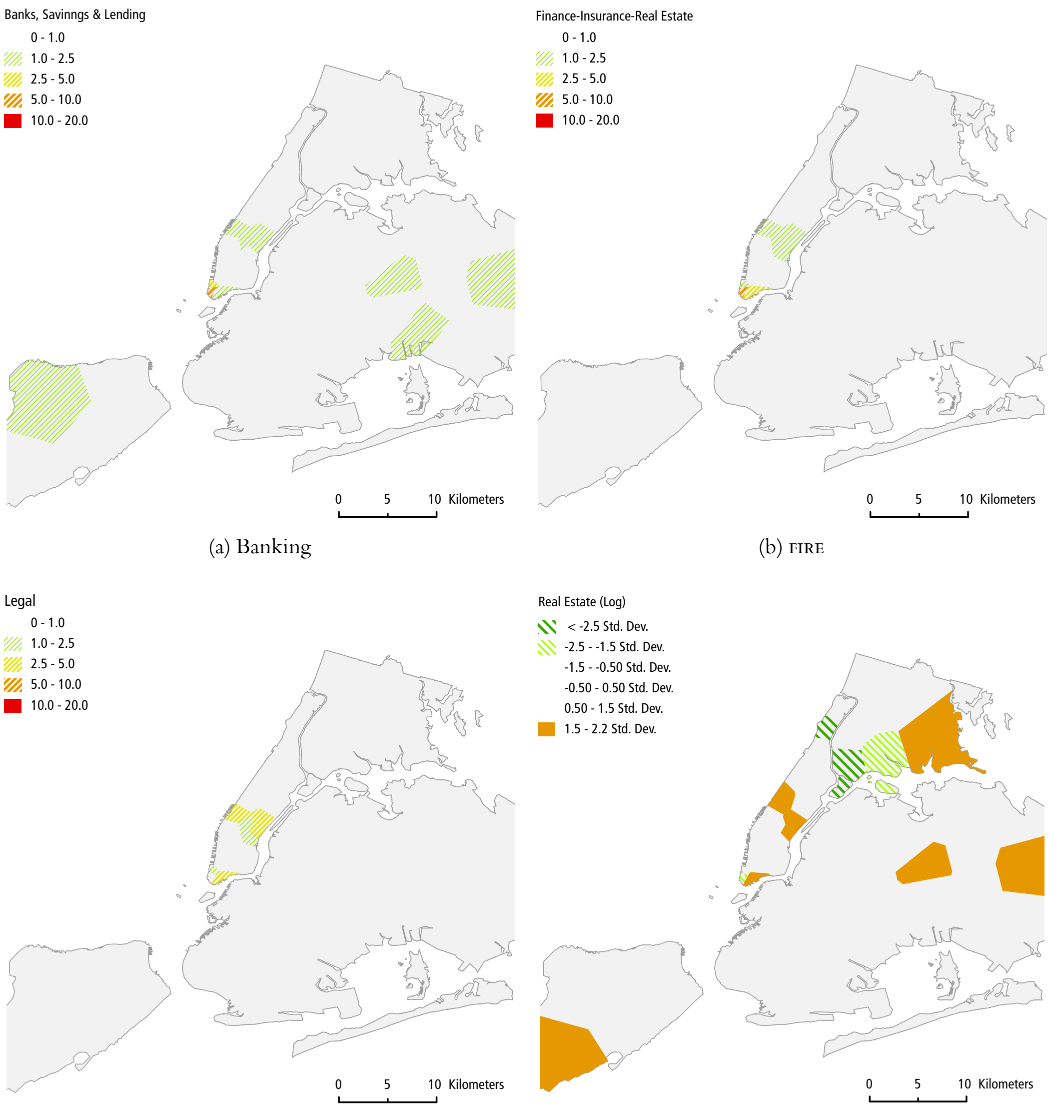


(c) Black



(d) White

Figure 10.4: Percentage of Households by Wire Centre



(a) Banking

(b) FIRE

(c) Legal

(d) Real Estate

Figure 10.5: NYC Location Quotients

London

Table 10.2 shows the results for the Lilliefors test against the various knowledge base groups and top-level SIC codes. Note that the results of the test are dependent upon the a user-specified threshold for rejecting the null-hypothesis: we could easily raise or lower this threshold to changes the results quite dramatically. Because I was looking to highlight areas with particularly high or low levels of industrial activity in a non-arbitrary manner, strict normality was not essential and so I opted for a relaxed test for normality with a significance threshold of 0.01. Some LQ distributions are undoubtedly left- or right-skewed from a purely normal distribution, but this is not considered enormously important for interpreting the results.

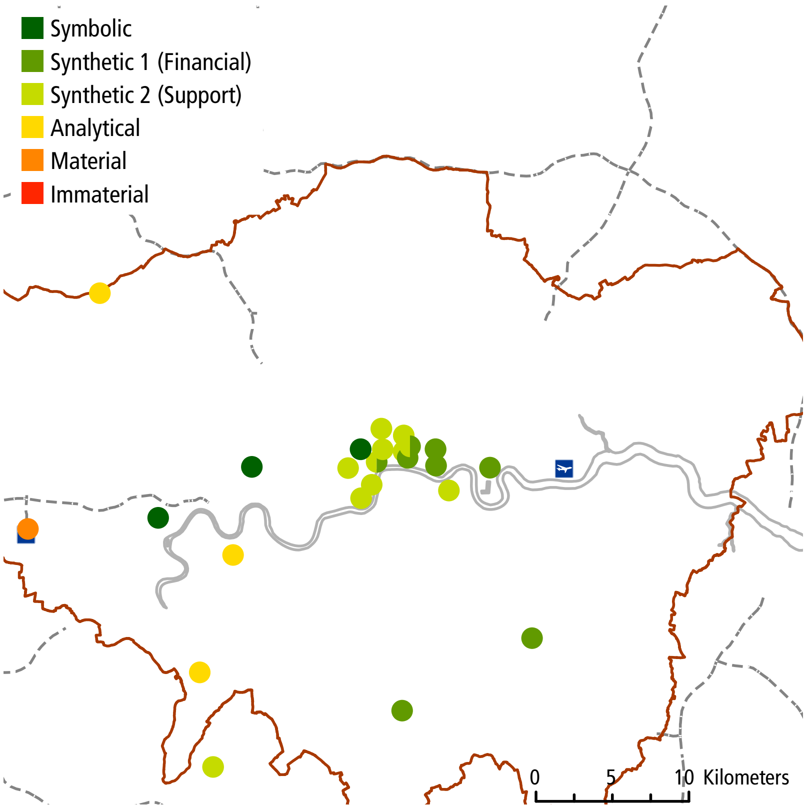


Figure 10.6: Significant Locations by Knowledge Base

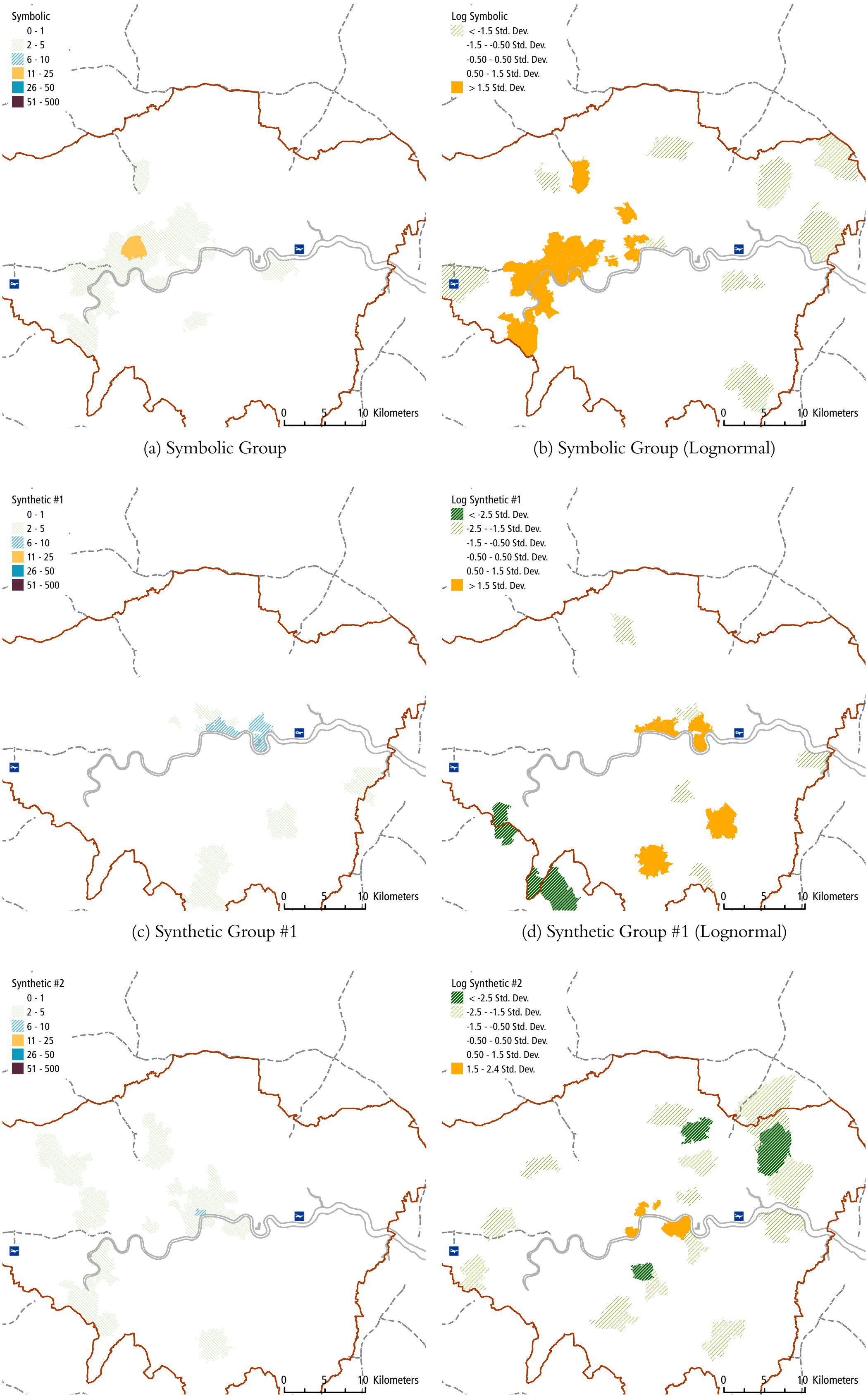
Table 10.3 shows the positive results from the Lilliefors test for 3-digit SIC codes and code groupings. In all cases, only the logarithmic LQs proved to be normally distributed although here, though after this transformation many industries and groups were found to have a largely normal dispersion. This result is undoubtedly at least partly a function of the smaller spatial units and larger geographical area covered by the London metro data set.

Table 10.2: Lognormal 1-Digit Industries & Knowledge Base Groups in London

Group/SIC Code	p-value	KS Statistic	Critical Value
Symbolic	$3.400000e^{-2}$	$6.756472e^{-2}$	$8.711307e^{-2}$
Synthetic #1	$2.700000e^{-2}$	$6.837871e^{-2}$	$8.628341e^{-2}$
Synthetic #2	$1.000000e^{-3}$	$9.006813e^{-2}$	$9.351312e^{-2}$
Analytical	$1.980000e^{-1}$	$5.387542e^{-2}$	$9.243265e^{-2}$
Material	$4.630000e^{-1}$	$4.491930e^{-2}$	$9.895010e^{-2}$
Immaterial	$8.900000e^{-2}$	$1.178963e^{-1}$	$1.867370e^{-1}$
SIC CE	$8.170000e^{-1}$	$7.766221e^{-2}$	$1.846034e^{-1}$
SIC D	$1.400000e^{-2}$	$7.496562e^{-2}$	$8.476711e^{-2}$
SIC GH	$4.200000e^{-2}$	$6.609079e^{-2}$	$9.444217e^{-2}$
SIC I	$1.660000e^{-1}$	$5.513915e^{-2}$	$8.669258e^{-2}$
SIC JK	$6.900000e^{-2}$	$6.280504e^{-2}$	$9.933967e^{-2}$
SIC LMN	$6.000000e^{-3}$	$7.729631e^{-2}$	$8.872986e^{-2}$
SIC OPQ	$2.000000e^{-1}$	$5.329781e^{-2}$	$9.430768e^{-2}$

Table 10.3: Lognormal 3-Digit Industries in London

Group/SIC Code	p-value	KS Statistic	Critical Value
Real Estate	$7.400000e^{-1}$	$3.845258e^{-2}$	$8.869149e^{-2}$
APS	$4.720000e^{-1}$	$4.495272e^{-2}$	$9.337105e^{-2}$
Cultural Activity	$2.810000e^{-1}$	$5.103897e^{-2}$	$8.455986e^{-2}$
SIC 602	$3.700000e^{-2}$	$6.768206e^{-2}$	$9.081601e^{-2}$
SIC 622	$4.000000e^{-3}$	$1.573856e^{-1}$	$1.713675e^{-1}$
SIC 651	$3.900000e^{-2}$	$6.734452e^{-2}$	$8.882586e^{-2}$
SIC 652	$2.370000e^{-1}$	$5.344637e^{-2}$	$9.120638e^{-2}$
SIC 660	$1.500000e^{-2}$	$9.342722e^{-2}$	$1.131218e^{-1}$
SIC 671	$7.000000e^{-3}$	$7.699805e^{-2}$	$9.130567e^{-2}$
SIC 672	$5.090000e^{-1}$	$4.543294e^{-2}$	$9.702657e^{-2}$
SIC 701	$7.060000e^{-1}$	$3.845258e^{-2}$	$8.518390e^{-2}$
SIC 721	$5.140000e^{-1}$	$4.382450e^{-2}$	$8.753588e^{-2}$
SIC 722	$9.530000e^{-1}$	$3.088929e^{-2}$	$8.858270e^{-2}$
SIC 723	$7.000000e^{-2}$	$6.542662e^{-2}$	$8.669382e^{-2}$
SIC 724	$1.100000e^{-2}$	$7.692361e^{-2}$	$8.673970e^{-2}$
SIC 731	$1.000000e^{-3}$	$9.796431e^{-2}$	$9.879732e^{-2}$
SIC 741	$5.540000e^{-1}$	$4.260711e^{-2}$	$8.856584e^{-2}$
SIC 742	$6.040000e^{-1}$	$4.196231e^{-2}$	$9.510404e^{-2}$
SIC 744	$4.620000e^{-1}$	$4.484201e^{-2}$	$9.590550e^{-2}$
SIC 921	$6.500000e^{-2}$	$6.465992e^{-2}$	$9.696224e^{-2}$
SIC 922	$1.800000e^{-2}$	$7.851444e^{-2}$	$9.159595e^{-2}$
SIC 925	$8.000000e^{-3}$	$7.511904e^{-2}$	$8.343634e^{-2}$



(a) Symbolic Group

(b) Symbolic Group (Lognormal)

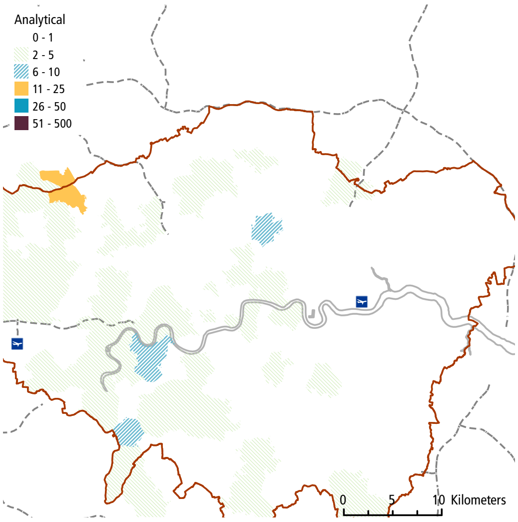
(c) Synthetic Group #1

(d) Synthetic Group #1 (Lognormal)

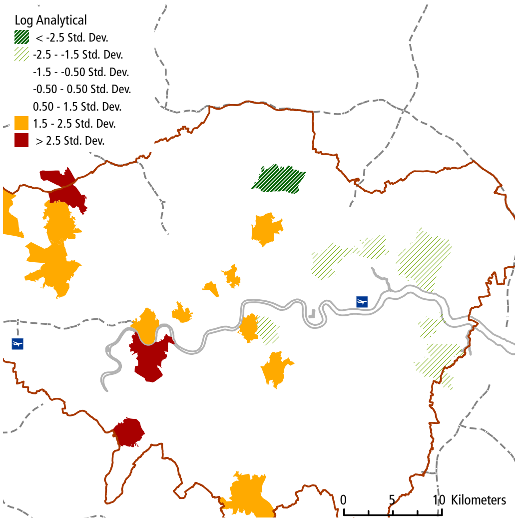
(e) Synthetic Group #2

(f) Synthetic Group #2 (Lognormal)

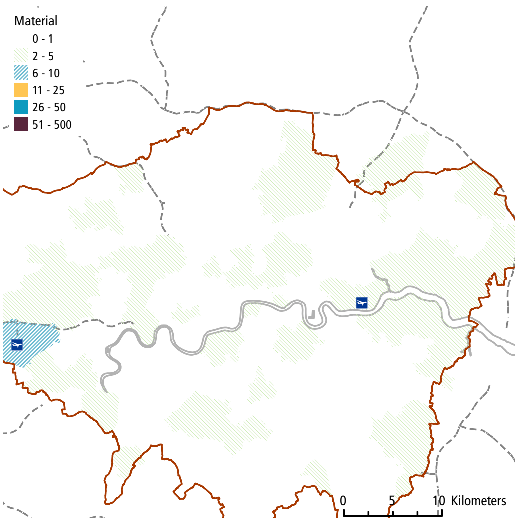
Figure 10.7: London Knowledge Base LQs (Part 1)



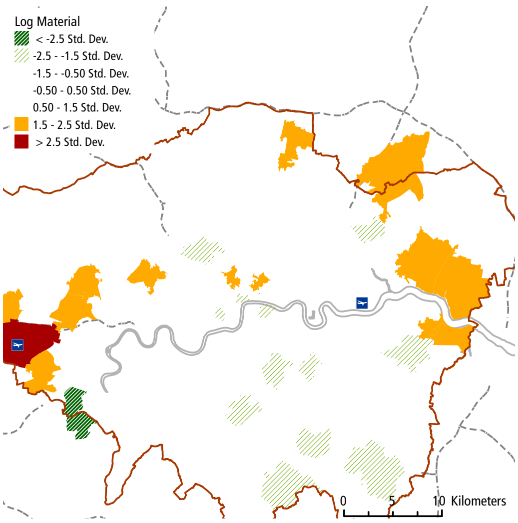
(a) Analytical Group



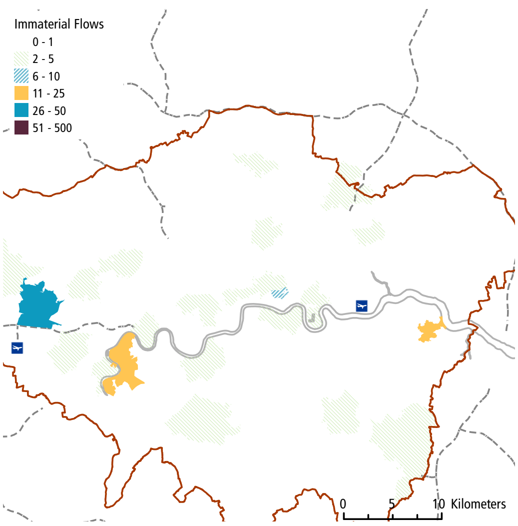
(b) Analytical Group (Lognormal)



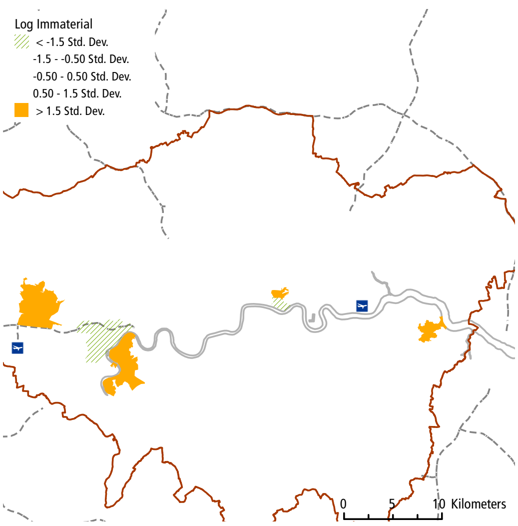
(c) Material Group



(d) Material Group (Lognormal)

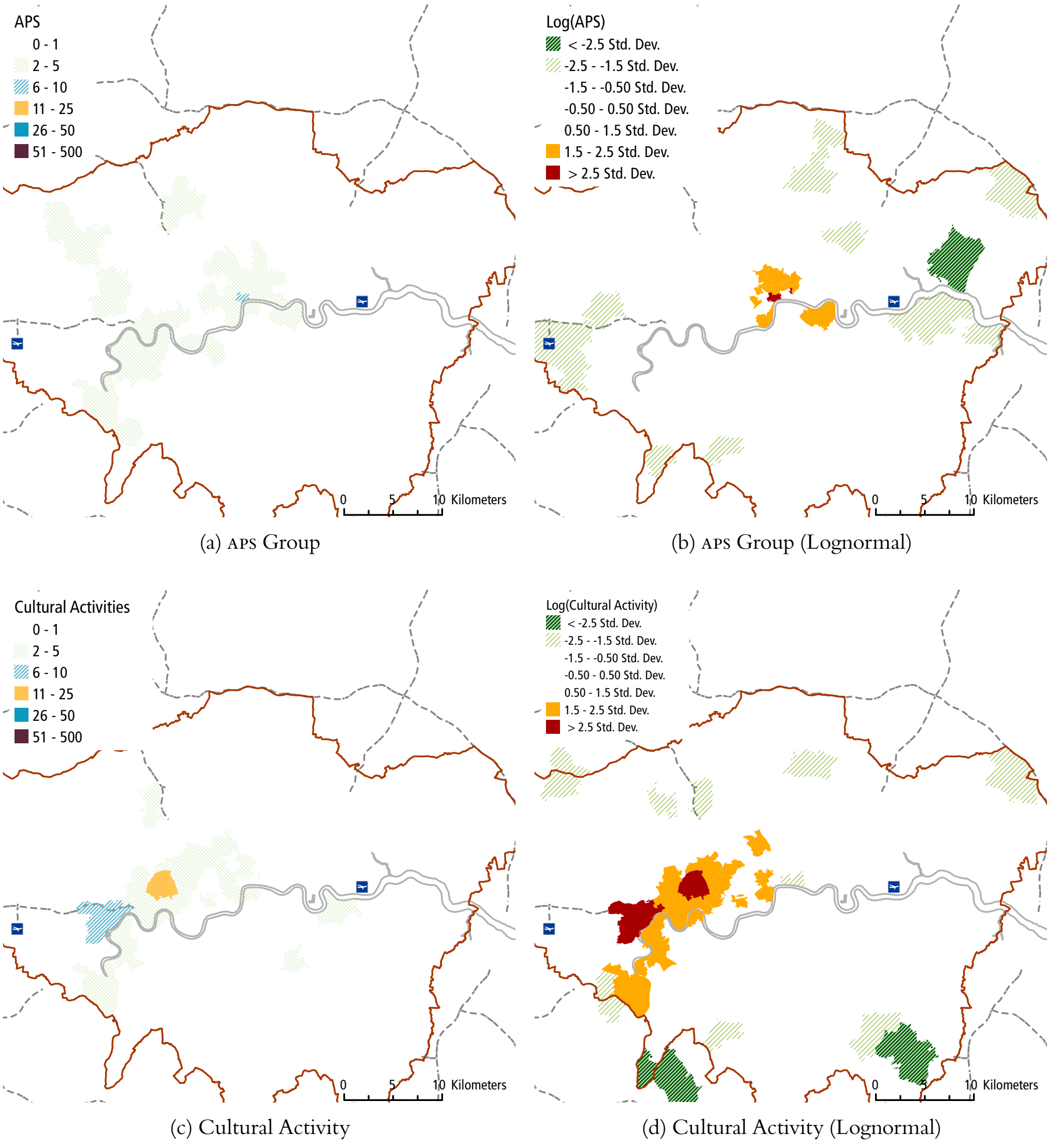


(e) Immaterial Group



(f) Immaterial Group (Lognormal)

Figure 10.8: London Knowledge Base LQs (Part 2)



(a) APS Group

(b) APS Group (Lognormal)

(c) Cultural Activity

(d) Cultural Activity (Lognormal)

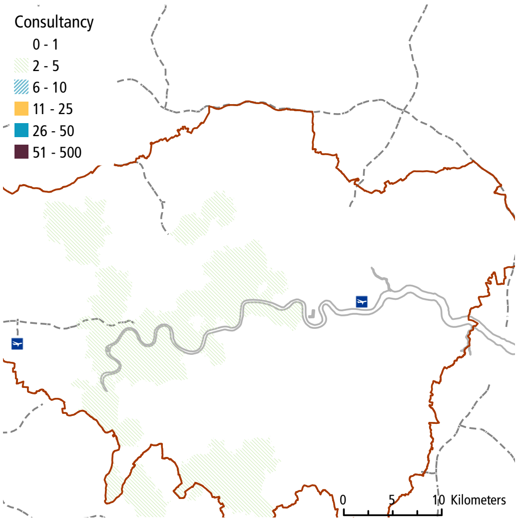
Figure 10.9: London NOMIS3 Group LQs

Table 10.4: Lognormal 4-Digit Industries in London

Group/SIC Code	p-value	KS Statistic	Critical Value
Cultural Production	$3.720000e^{-1}$	$6.400970e^{-2}$	$1.236101e^{-1}$
ICT	$3.400000e^{-2}$	$7.392131e^{-2}$	$1.023281e^{-1}$
Legal & Accountancy	$1.470000e^{-1}$	$6.525564e^{-2}$	$9.646476e^{-2}$
Logistics	$7.260000e^{-1}$	$5.297770e^{-2}$	$1.163476e^{-1}$
R&D	$3.030000e^{-1}$	$1.058321e^{-1}$	$1.869025e^{-1}$
SIC 6010	$3.790000e^{-1}$	$1.033604e^{-1}$	$1.956083e^{-1}$
SIC 6024	$7.410000e^{-1}$	$6.489555e^{-2}$	$1.489214e^{-1}$
SIC 6110	$5.700000e^{-2}$	$2.505669e^{-1}$	$3.213004e^{-1}$
SIC 6210	$4.640000e^{-1}$	$1.384792e^{-1}$	$2.859780e^{-1}$
SIC 6220	$8.230000e^{-1}$	$1.778165e^{-1}$	$4.209183e^{-1}$
SIC 6312	$5.990000e^{-1}$	$7.889068e^{-2}$	$1.882985e^{-1}$
SIC 6321	$5.440000e^{-1}$	$7.047760e^{-2}$	$1.428104e^{-1}$
SIC 6322	$2.000000e^{-2}$	$2.741673e^{-1}$	$3.394388e^{-1}$
SIC 6323	$9.590000e^{-1}$	$1.220596e^{-1}$	$3.386641e^{-1}$
SIC 6512	$6.900000e^{-2}$	$7.187157e^{-2}$	$1.074469e^{-1}$
SIC 6521	$5.250000e^{-1}$	$1.564900e^{-1}$	$3.059370e^{-1}$
SIC 6522	$8.680000e^{-1}$	$7.993685e^{-2}$	$2.287873e^{-1}$
SIC 6523	$1.260000e^{-1}$	$1.230549e^{-1}$	$1.897315e^{-1}$
SIC 6601	$6.260000e^{-1}$	$1.170421e^{-1}$	$2.594921e^{-1}$
SIC 6603	$3.630000e^{-1}$	$9.862195e^{-2}$	$1.695903e^{-1}$
SIC 6711	$7.950000e^{-1}$	$1.588443e^{-1}$	$4.123659e^{-1}$
SIC 6712	$1.330000e^{-1}$	$1.336660e^{-1}$	$2.221808e^{-1}$
SIC 6713	$7.810000e^{-1}$	$7.066747e^{-2}$	$1.668538e^{-1}$
SIC 6720	$7.450000e^{-1}$	$6.581914e^{-2}$	$1.415627e^{-1}$
SIC 7011	$9.520000e^{-1}$	$4.861497e^{-2}$	$1.440064e^{-1}$
SIC 7020	$6.450000e^{-1}$	$4.871314e^{-2}$	$1.094285e^{-1}$
SIC 7031	$6.100000e^{-2}$	$8.375348e^{-2}$	$1.319683e^{-1}$
SIC 7032	$1.300000e^{-2}$	$1.092458e^{-1}$	$1.354521e^{-1}$

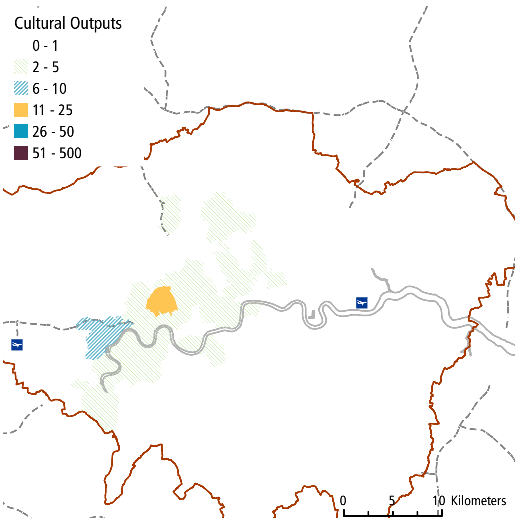
Table 10.5: Lognormal 4-Digit Industries in London (cont'd)

Group/SIC Code	p-value	KS Statistic	Critical Value
SIC 7210	$2.600000e^{-1}$	$1.532385e^{-1}$	$2.854538e^{-1}$
SIC 7221	$5.630000e^{-1}$	$1.346762e^{-1}$	$2.710418e^{-1}$
SIC 7222	$9.200000e^{-2}$	$7.170814e^{-2}$	$1.057729e^{-1}$
SIC 7230	$6.840000e^{-1}$	$9.031456e^{-2}$	$2.209549e^{-1}$
SIC 7240	$2.560000e^{-1}$	$1.457600e^{-1}$	$2.464538e^{-1}$
SIC 7250	$7.310000e^{-1}$	$9.460447e^{-2}$	$2.230398e^{-1}$
SIC 7260	$2.440000e^{-1}$	$8.580356e^{-2}$	$1.527855e^{-1}$
SIC 7310	$2.840000e^{-1}$	$1.058321e^{-1}$	$2.037472e^{-1}$
SIC 7320	$5.830000e^{-1}$	$2.246251e^{-1}$	$4.278964e^{-1}$
SIC 7411	$1.900000e^{-2}$	$9.048149e^{-2}$	$1.164671e^{-1}$
SIC 7412	$1.940000e^{-1}$	$7.346485e^{-2}$	$1.129332e^{-1}$
SIC 7413	$5.920000e^{-1}$	$8.112338e^{-2}$	$1.691187e^{-1}$
SIC 7415	$9.060000e^{-1}$	$4.992502e^{-2}$	$1.273721e^{-1}$
SIC 7420	$4.740000e^{-1}$	$5.528010e^{-2}$	$1.037827e^{-1}$
SIC 7440	$3.120000e^{-1}$	$8.173152e^{-2}$	$1.392327e^{-1}$
SIC 7486	$1.780000e^{-1}$	$1.483763e^{-1}$	$2.433108e^{-1}$
SIC 7487	$9.100000e^{-2}$	$6.398876e^{-2}$	$9.805545e^{-2}$
SIC 9211	$7.940000e^{-1}$	$7.710466e^{-2}$	$2.011310e^{-1}$
SIC 9212	$4.620000e^{-1}$	$1.474237e^{-1}$	$2.965349e^{-1}$
SIC 9213	$8.060000e^{-1}$	$7.982196e^{-2}$	$1.939093e^{-1}$
SIC 9220	$4.080000e^{-1}$	$9.498936e^{-2}$	$1.651156e^{-1}$
SIC 9231	$2.200000e^{-2}$	$1.124051e^{-1}$	$1.373046e^{-1}$
SIC 9232	$3.960000e^{-1}$	$1.304972e^{-1}$	$2.582476e^{-1}$
SIC 9234	$4.100000e^{-2}$	$2.433219e^{-1}$	$3.127824e^{-1}$

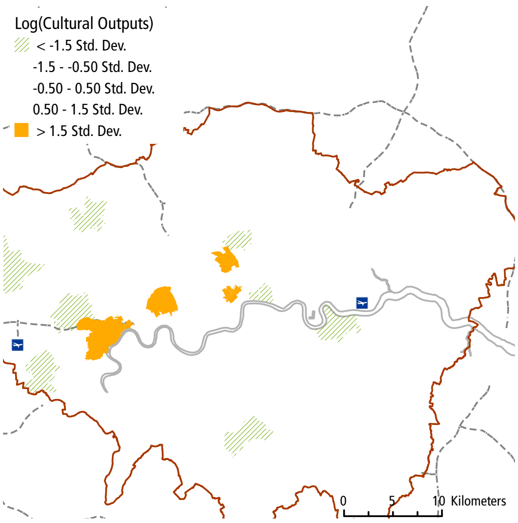


(a) Consultancy

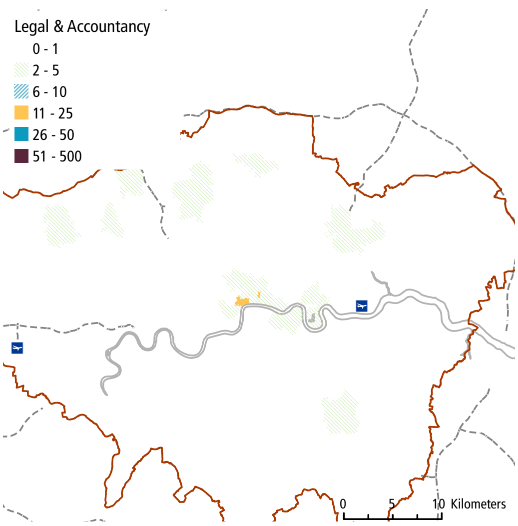
(b) Consultancy (Lognormal)



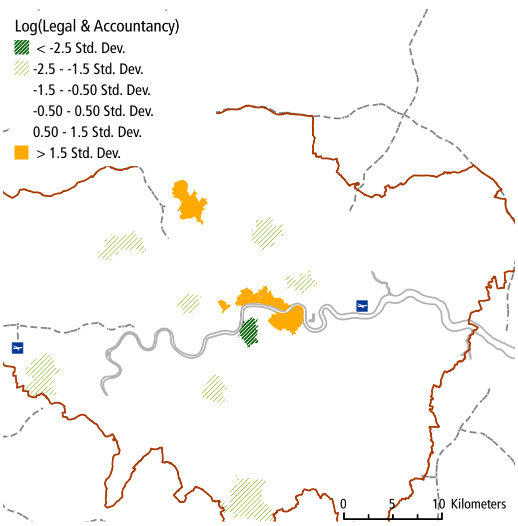
(c) Cultural Production



(d) Cultural Production (Lognormal)

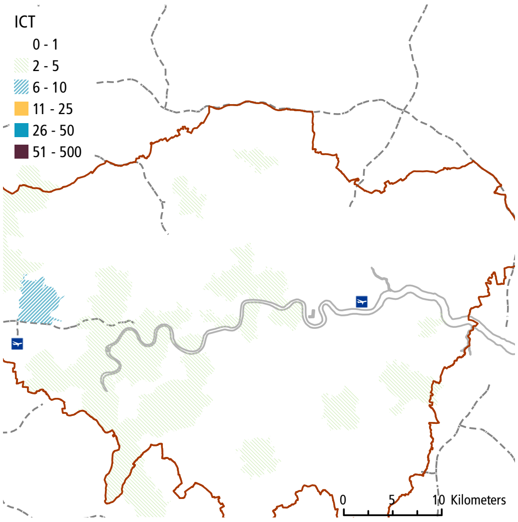


(e) Legal & Accountancy

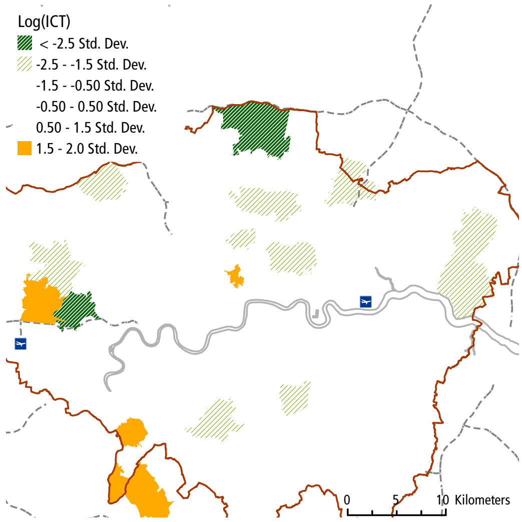


(f) Legal & Accountancy (Lognormal)

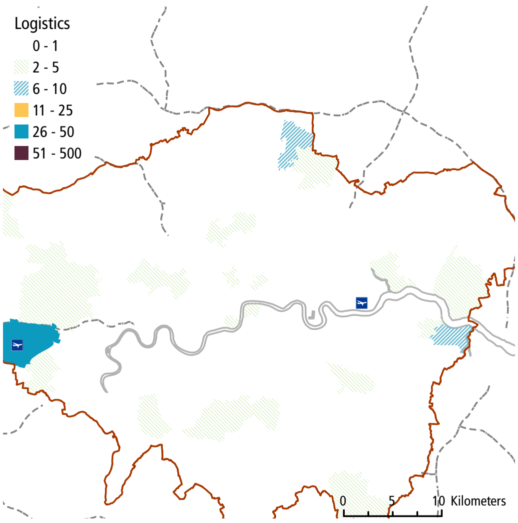
Figure 10.10: London NOMIS4 Group LQs (Part 1)



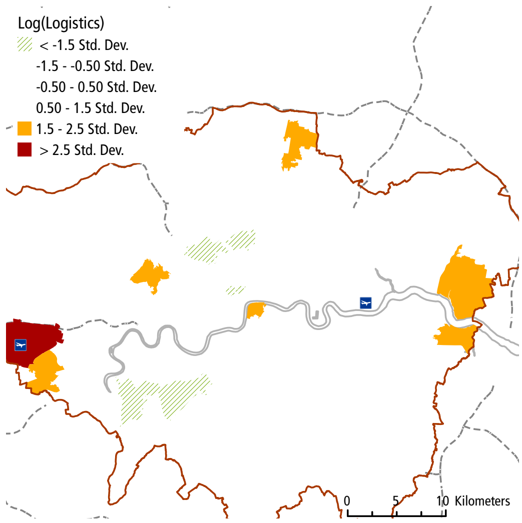
(a) ICT



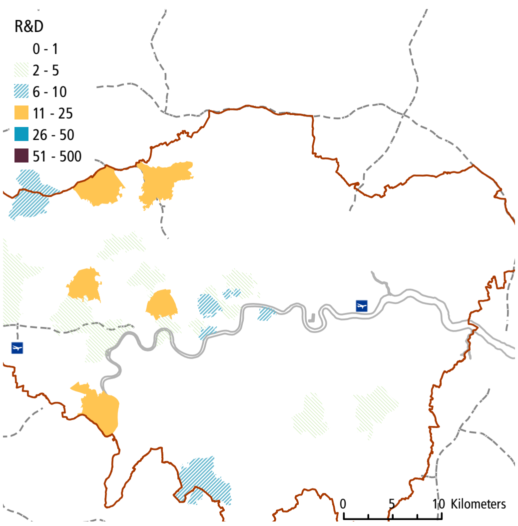
(b) ICT (Lognormal)



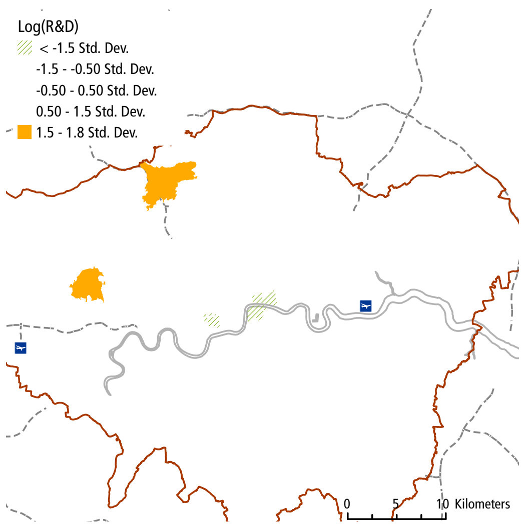
(c) Logistics



(d) Logistics (Lognormal)

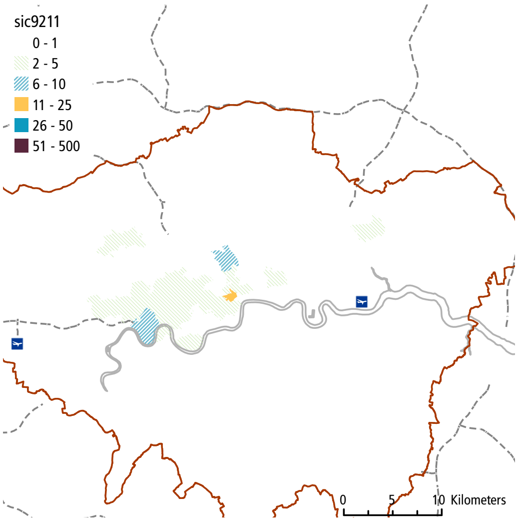


(e) R&D

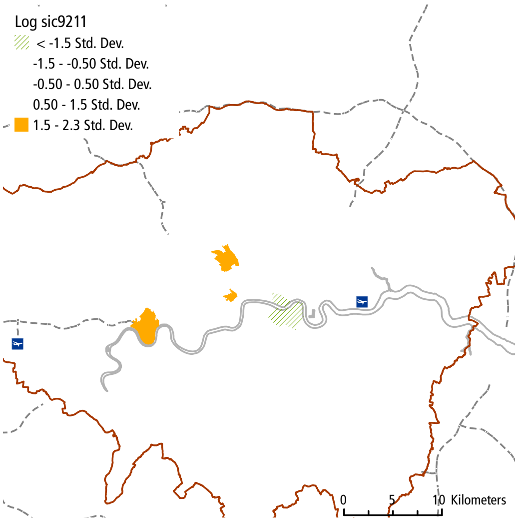


(f) R&D (Lognormal)

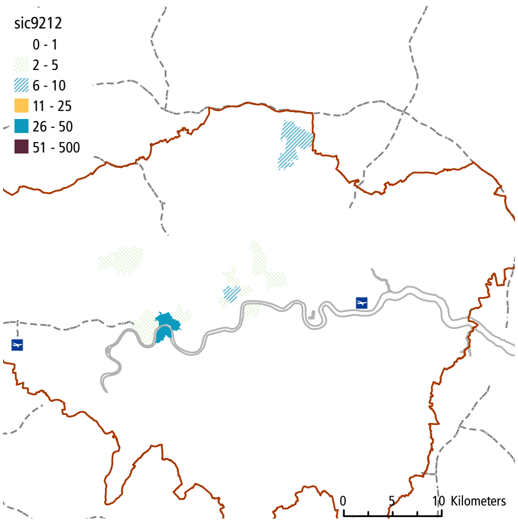
Figure 10.11: London NOMIS4 Group LQs (Part 2)



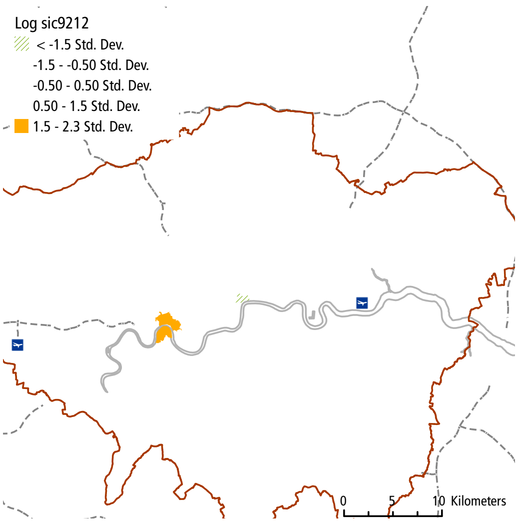
(a) Film & Video Production



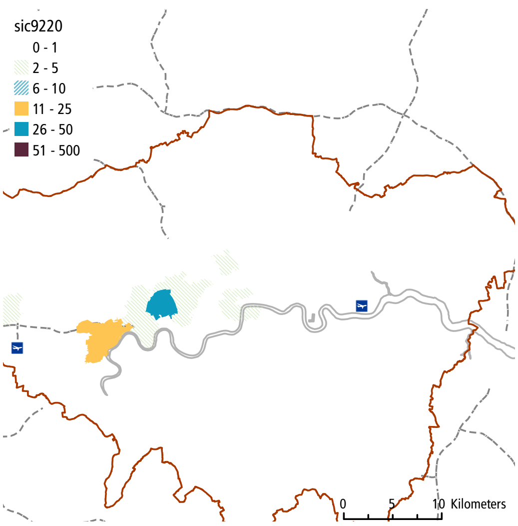
(b) Film & Video Production (Lognormal)



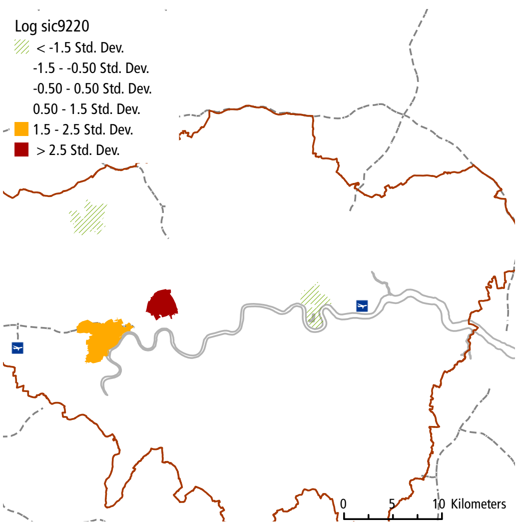
(c) Film & Video Distribution



(d) Film & Video Distribution (Lognormal)

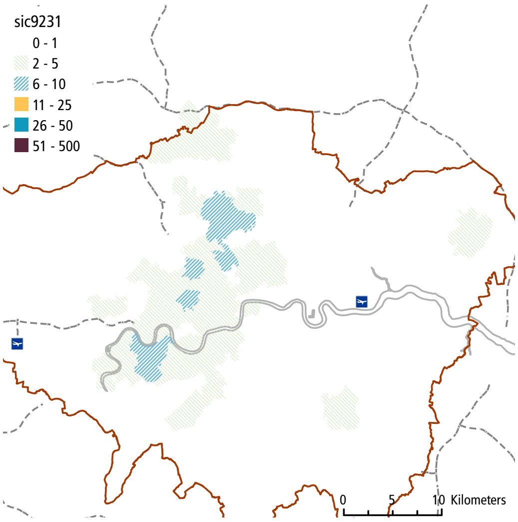


(e) Radio & TV



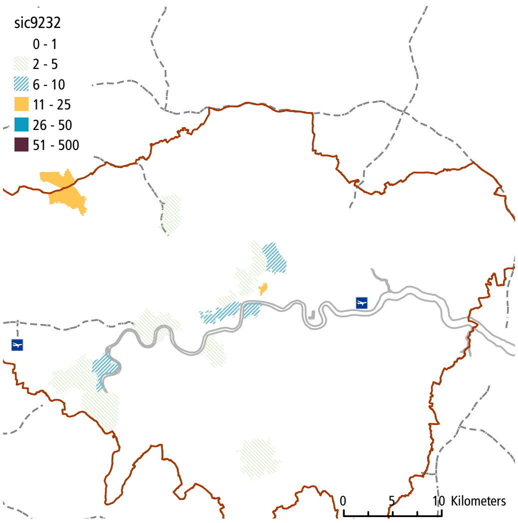
(f) Radio & TV (Lognormal)

Figure 10.12: London Symbolic LQs (Part 1)

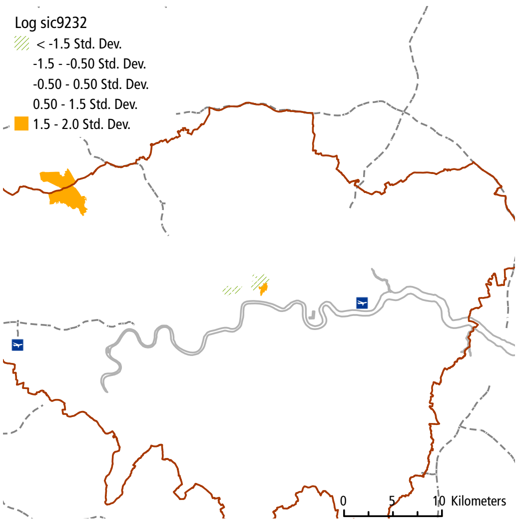


(a) Artistic & Literary

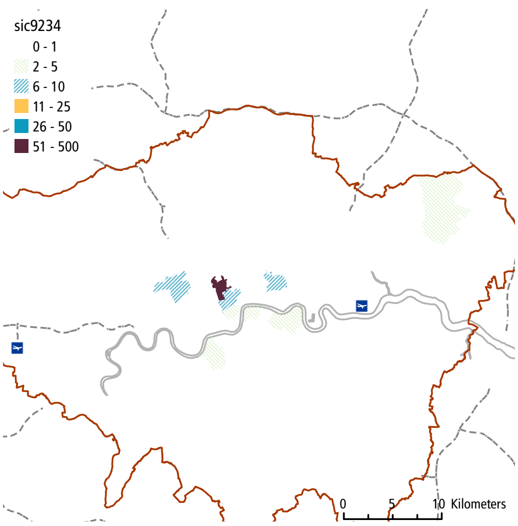
(b) Artistic & Literary (Lognormal)



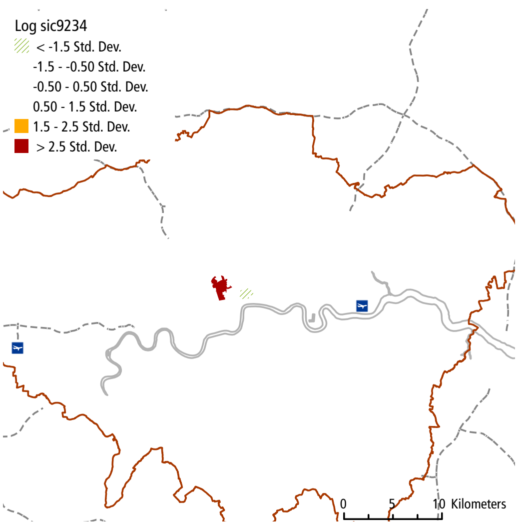
(c) Operation of Arts Facilities



(d) Operation of Arts Facilities (Lognormal)

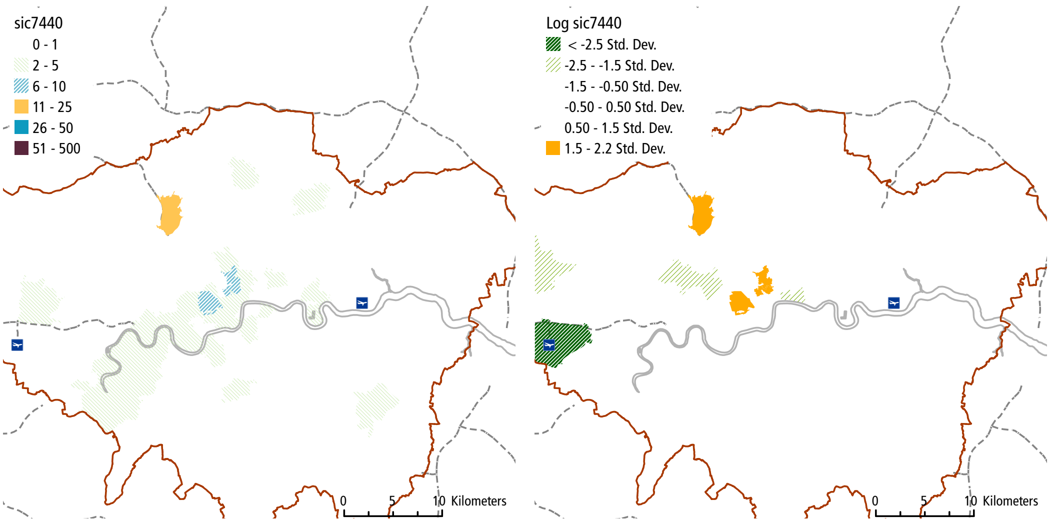


(e) Other Entertainment



(f) Other Entertainment (Lognormal)

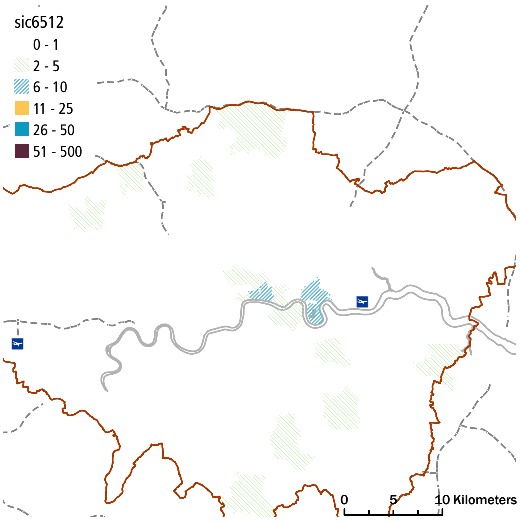
Figure 10.13: London Symbolic LQs (Part 2)



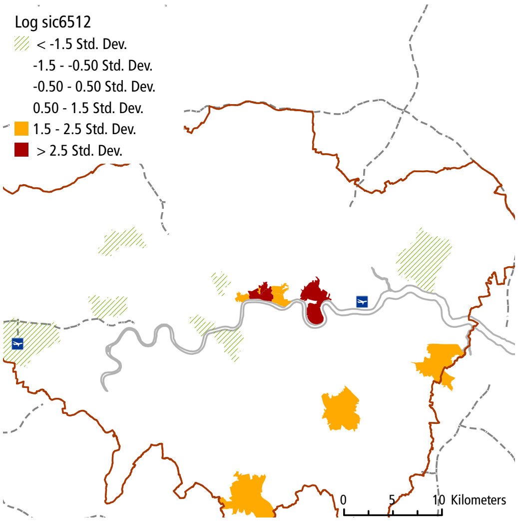
(a) Advertising

(b) Advertising (Lognormal)

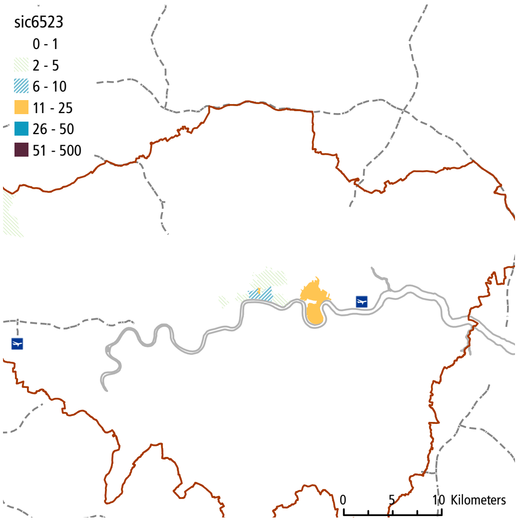
Figure 10.14: London Symbolic LQs (Part 3)



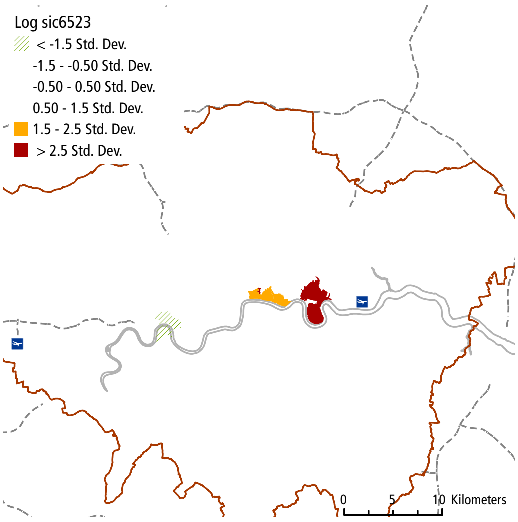
(a) Other Monetary Intermediation



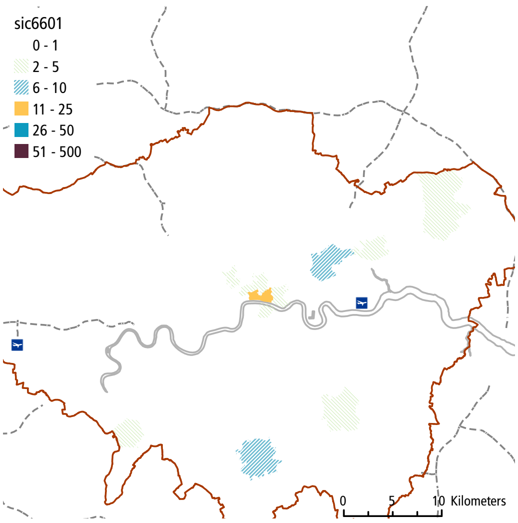
(b) Other Monetary Intermediation (Lognormal)



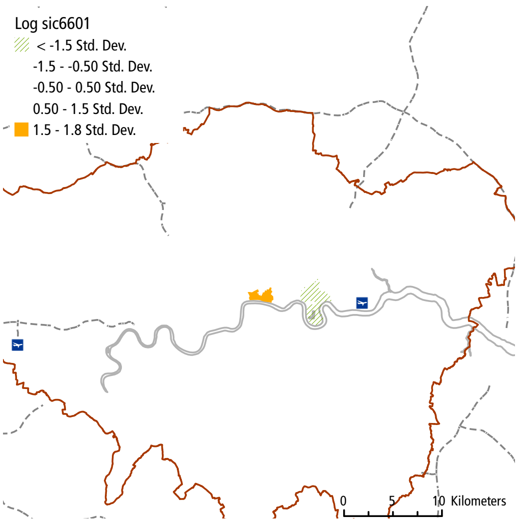
(c) Other Financial Intermediation



(d) Other Financial Intermediation (Lognormal)

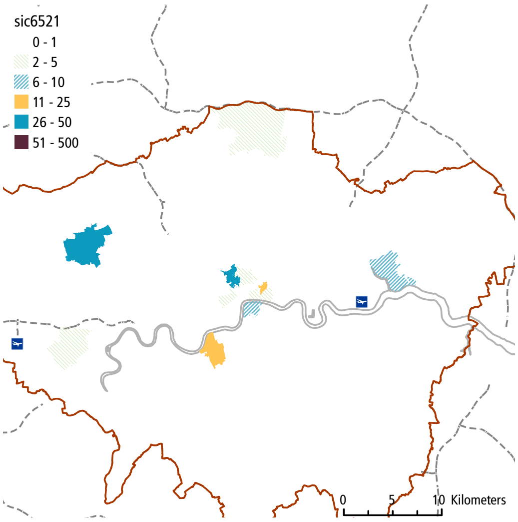


(e) Life Insurance

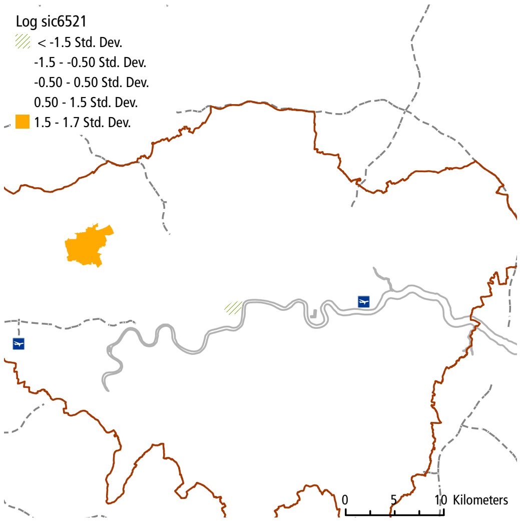


(f) Life Insurance (Lognormal)

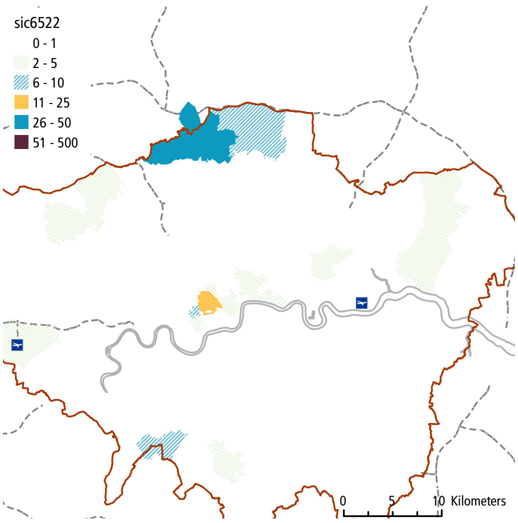
Figure 10.15: London Synthetic Group #1 LQs (Part 1)



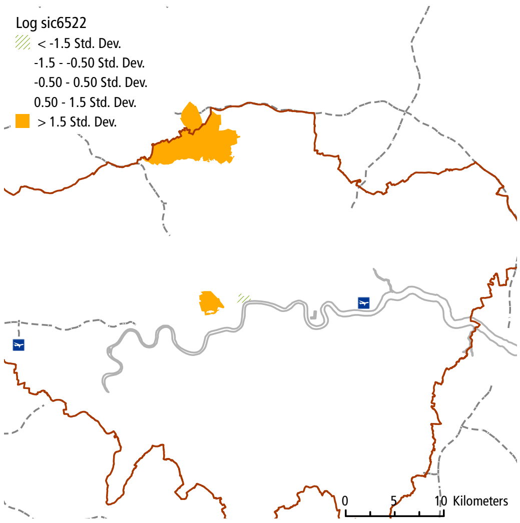
(a) Financial Leasing



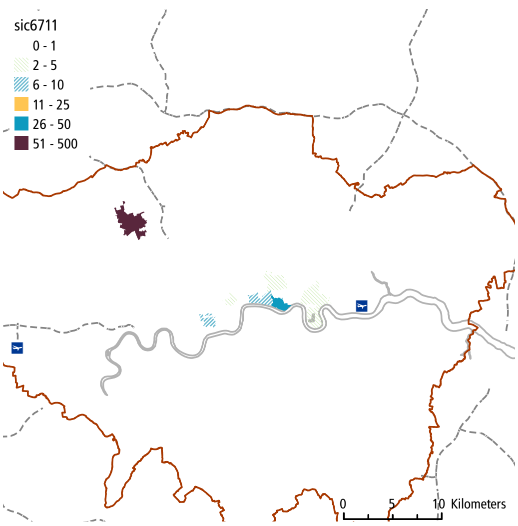
(b) Financial Leasing (Lognormal)



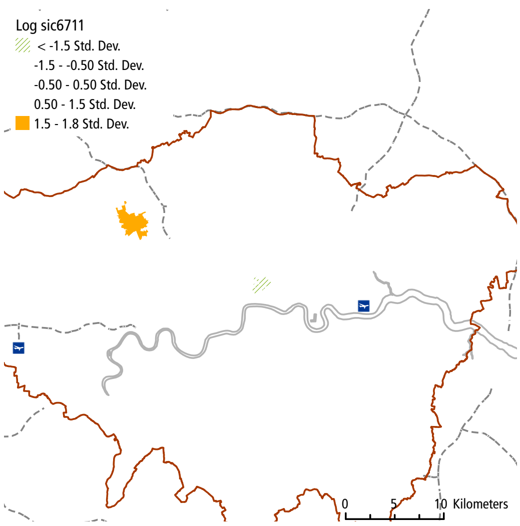
(c) Other Credit Granting



(d) Other Credit Granting (Lognormal)

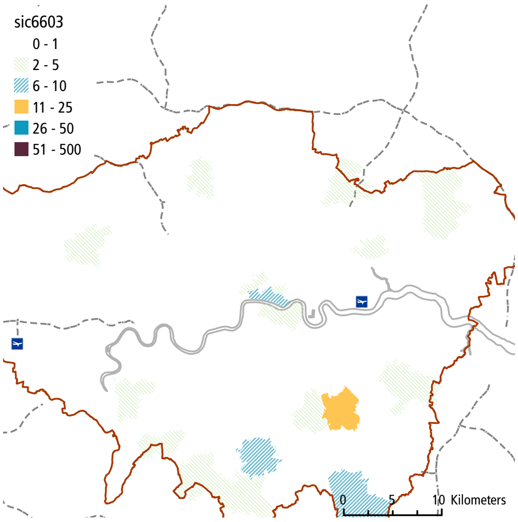


(e) Administration of Financial Markets

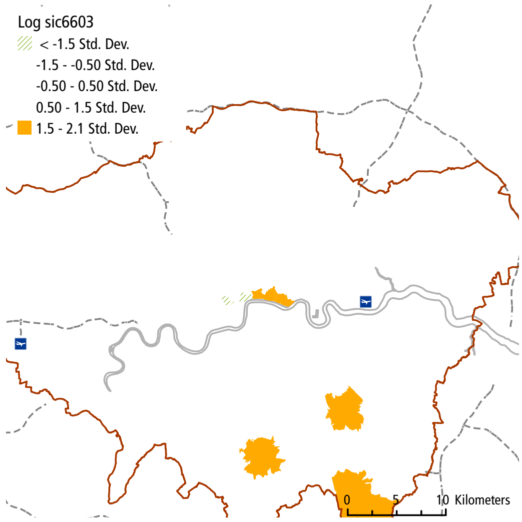


(f) Administration of Financial Markets (Lognormal)

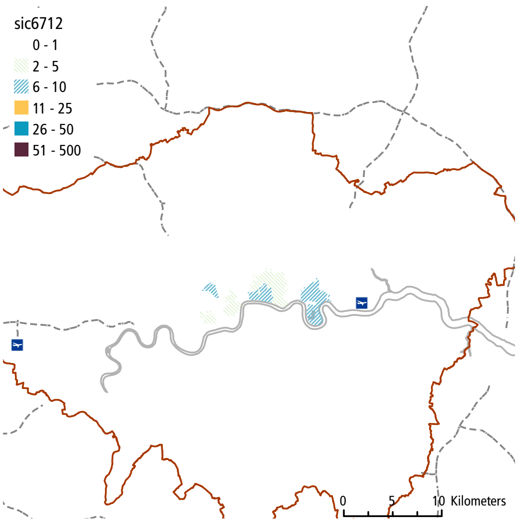
Figure 10.16: London Synthetic Group #1 LQs (Part 2)



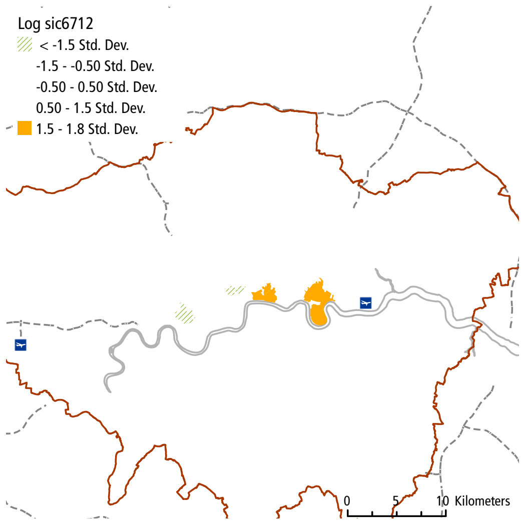
(a) Non-Life Insurance



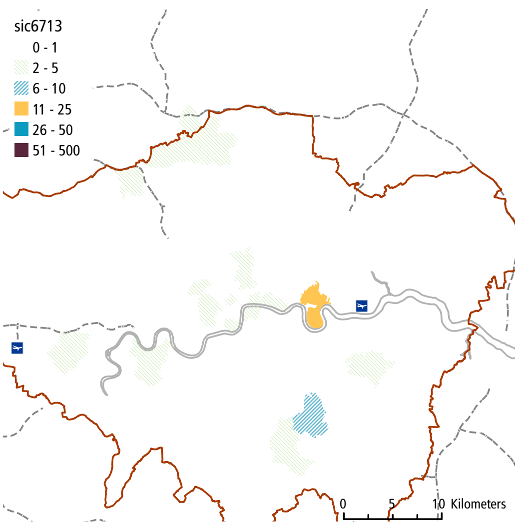
(b) Non-Life Insurance (Lognormal)



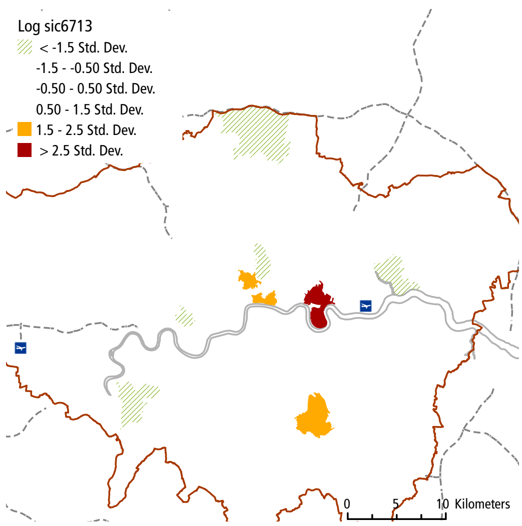
(c) Brokering & Fund Management



(d) Brokering & Fund Management (Lognormal)

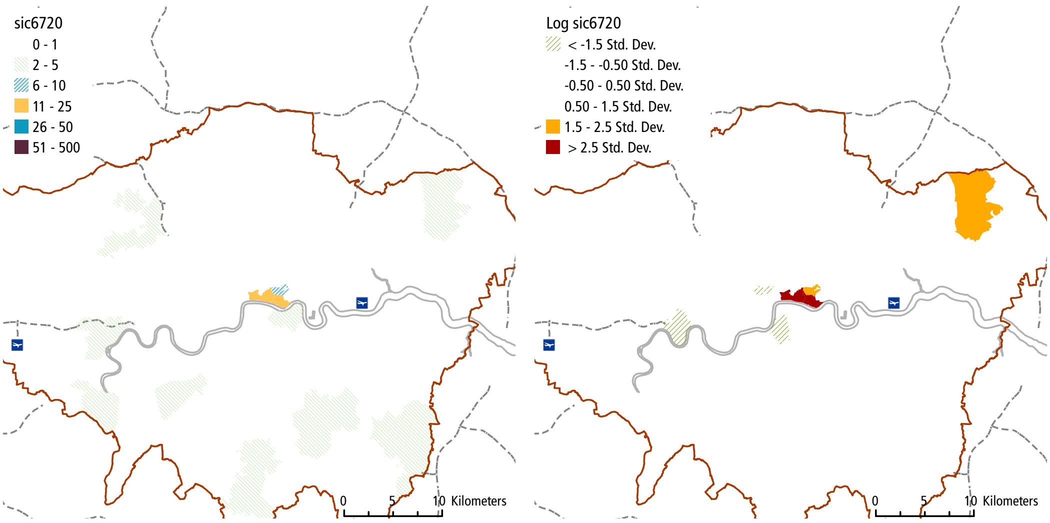


(e) Financial Intermediation Auxiliary



(f) Financial Intermediation Auxiliary (Lognormal)

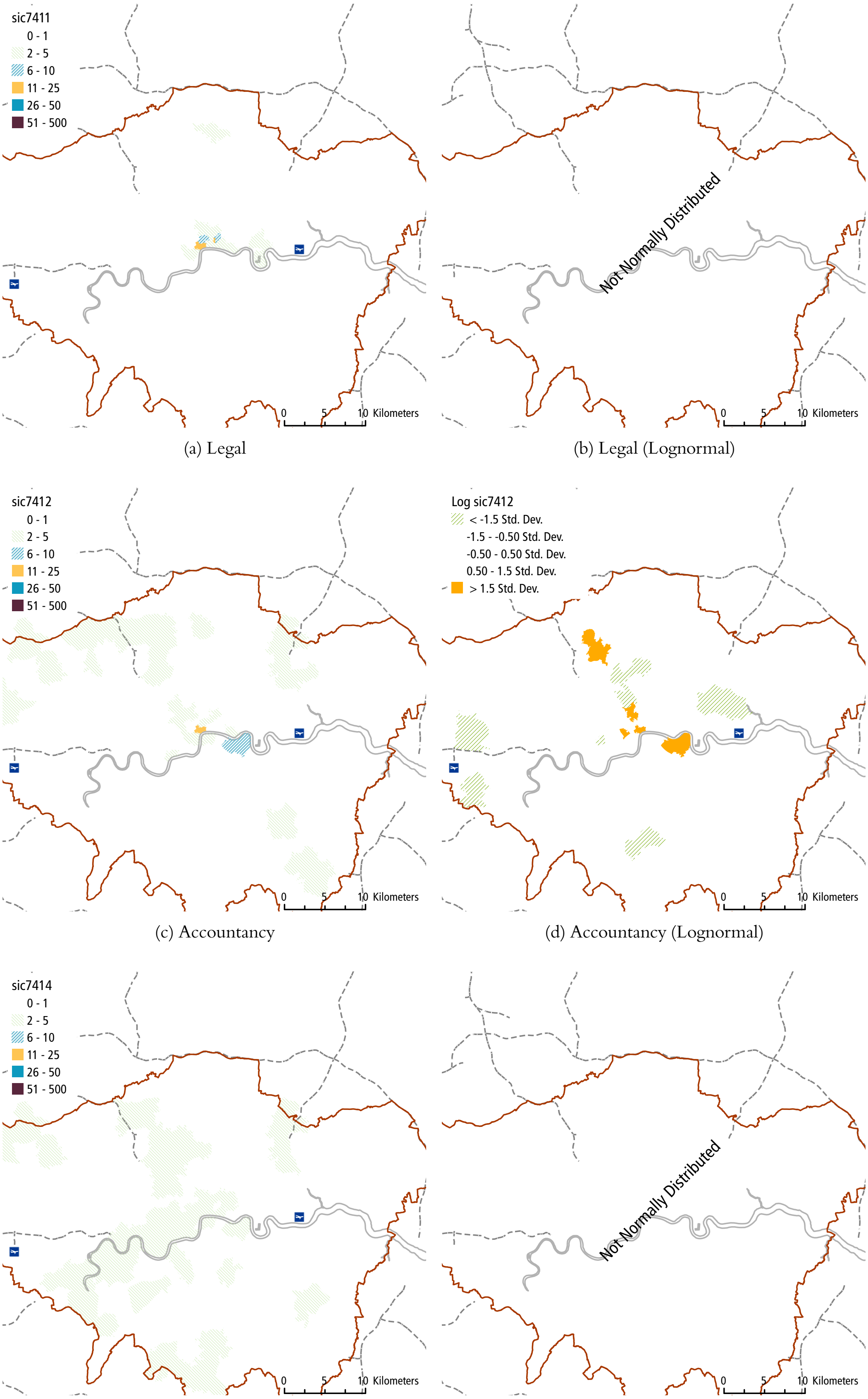
Figure 10.17: London Synthetic Group #1 LQs (Part 3)



(a) Insurance Auxiliary

(b) Insurance Auxiliary (Lognormal)

Figure 10.18: London Synthetic Group #1 LQs (Part 4)



(a) Legal

(b) Legal (Lognormal)

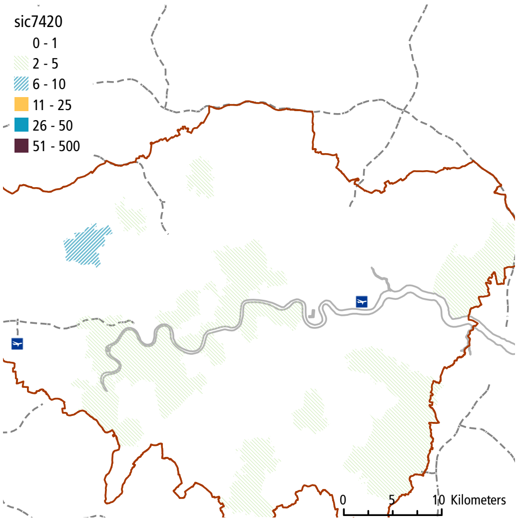
(c) Accountancy

(d) Accountancy (Lognormal)

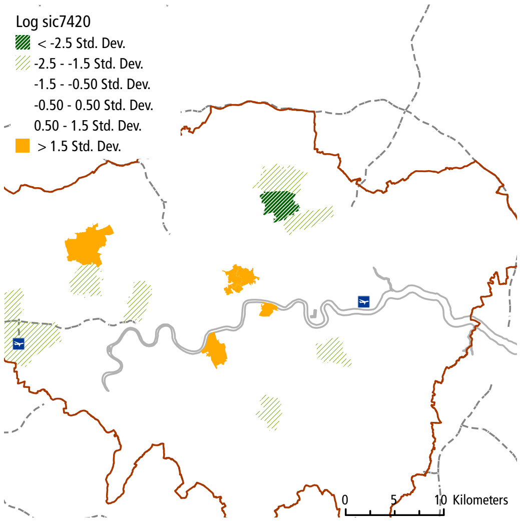
(e) Business Management Consultancy

(f) Business Management Consultancy (Lognormal)

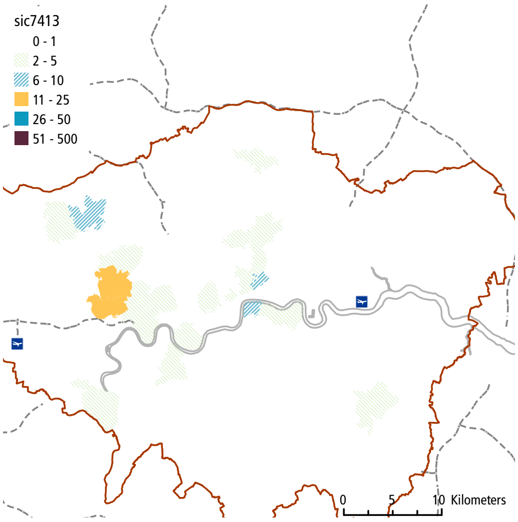
Figure 10.19: London Synthetic Group #2 LQs (Part 1)



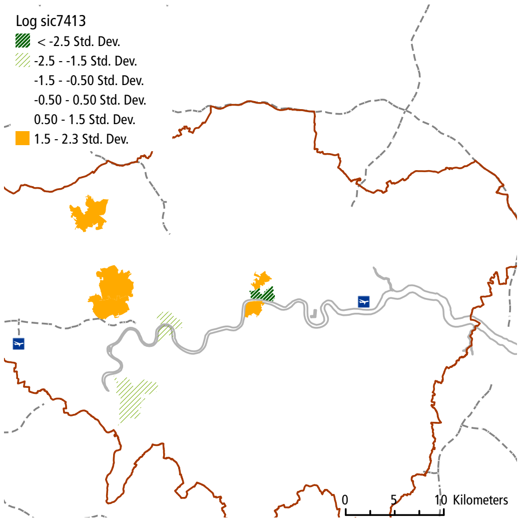
(a) Architecture & Engineering



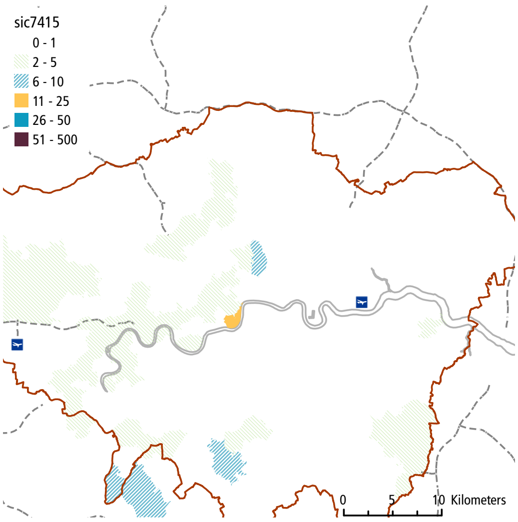
(b) Architecture & Engineering (Lognormal)



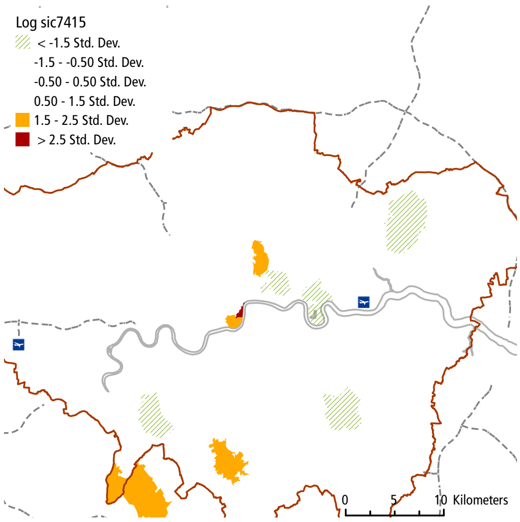
(c) Market Research



(d) Market Research (Lognormal)

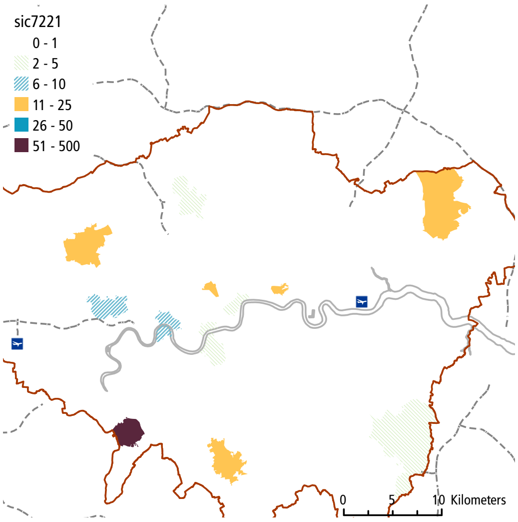


(e) Management Activities of Holding Companies

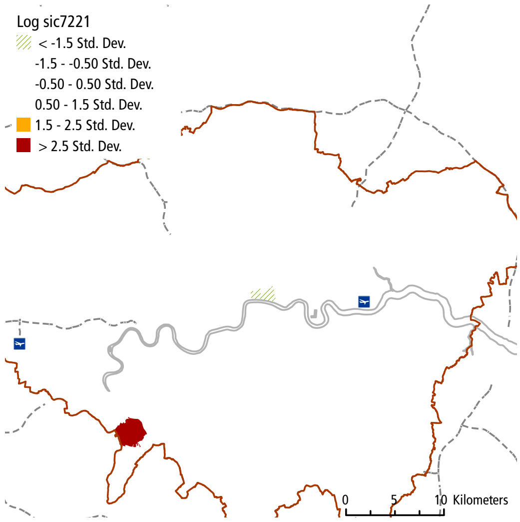


(f) Management Activities of Holding Companies (Lognormal)

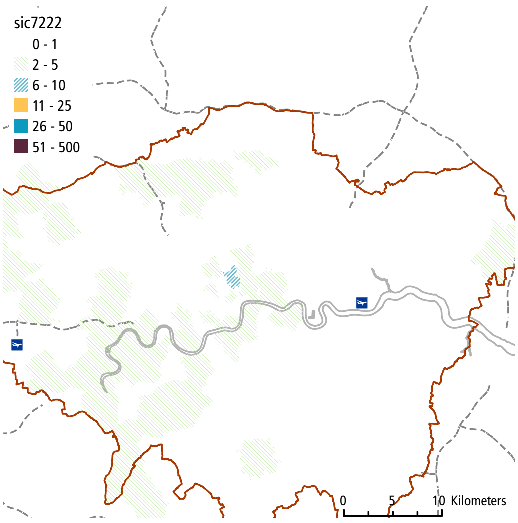
Figure 10.20: London Synthetic Group #2 LQs (Part 2)



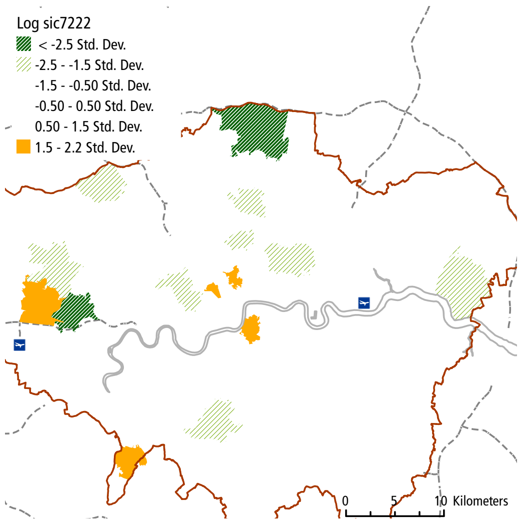
(a) Software Publishing



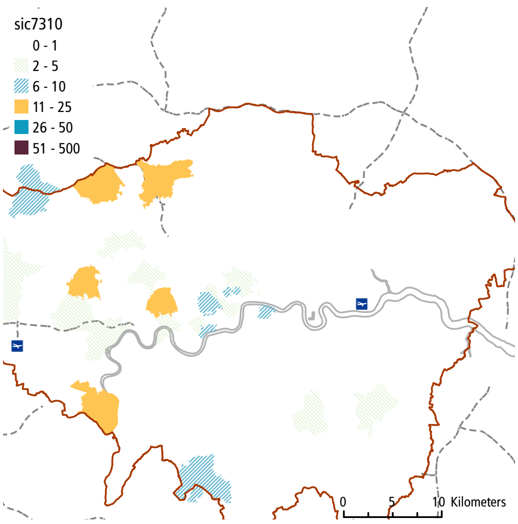
(b) Software Publishing (Lognormal)



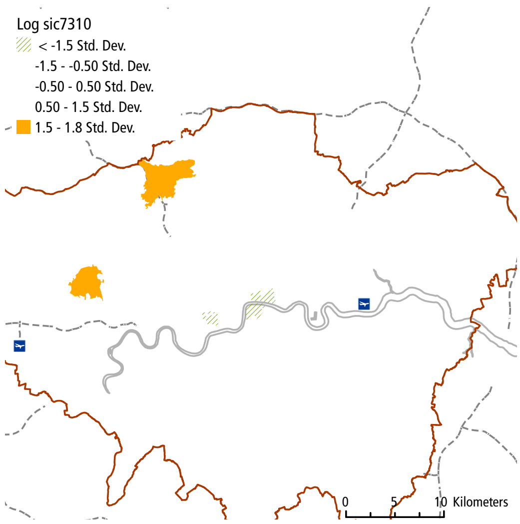
(c) Other Software Consultancy



(d) Other Software Consultancy (Lognormal)

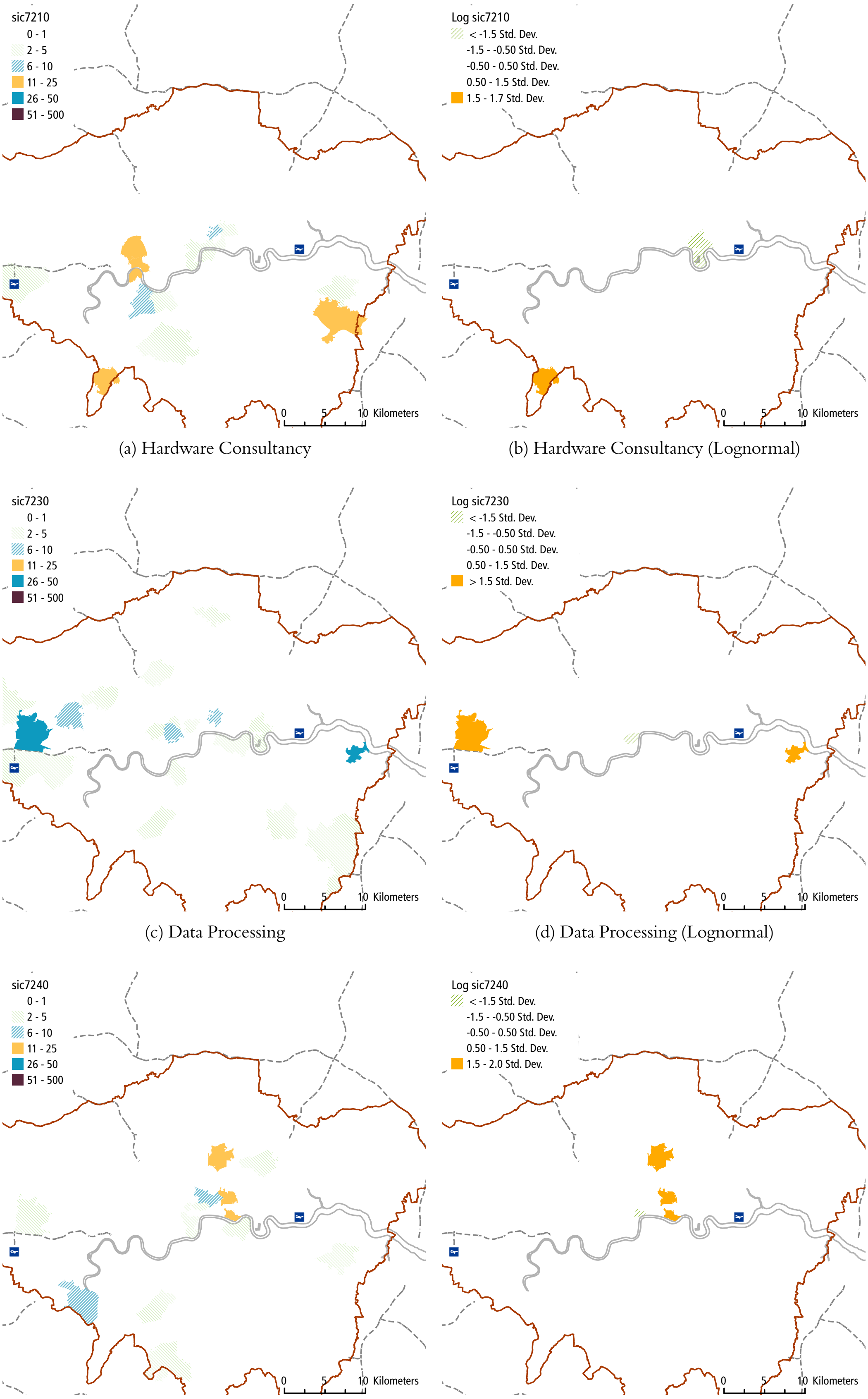


(e) R&D in Natural Sciences



(f) R&D in Natural Sciences (Lognormal)

Figure 10.21: London Analytical Group LQs (Part 1)



(a) Hardware Consultancy

(b) Hardware Consultancy (Lognormal)

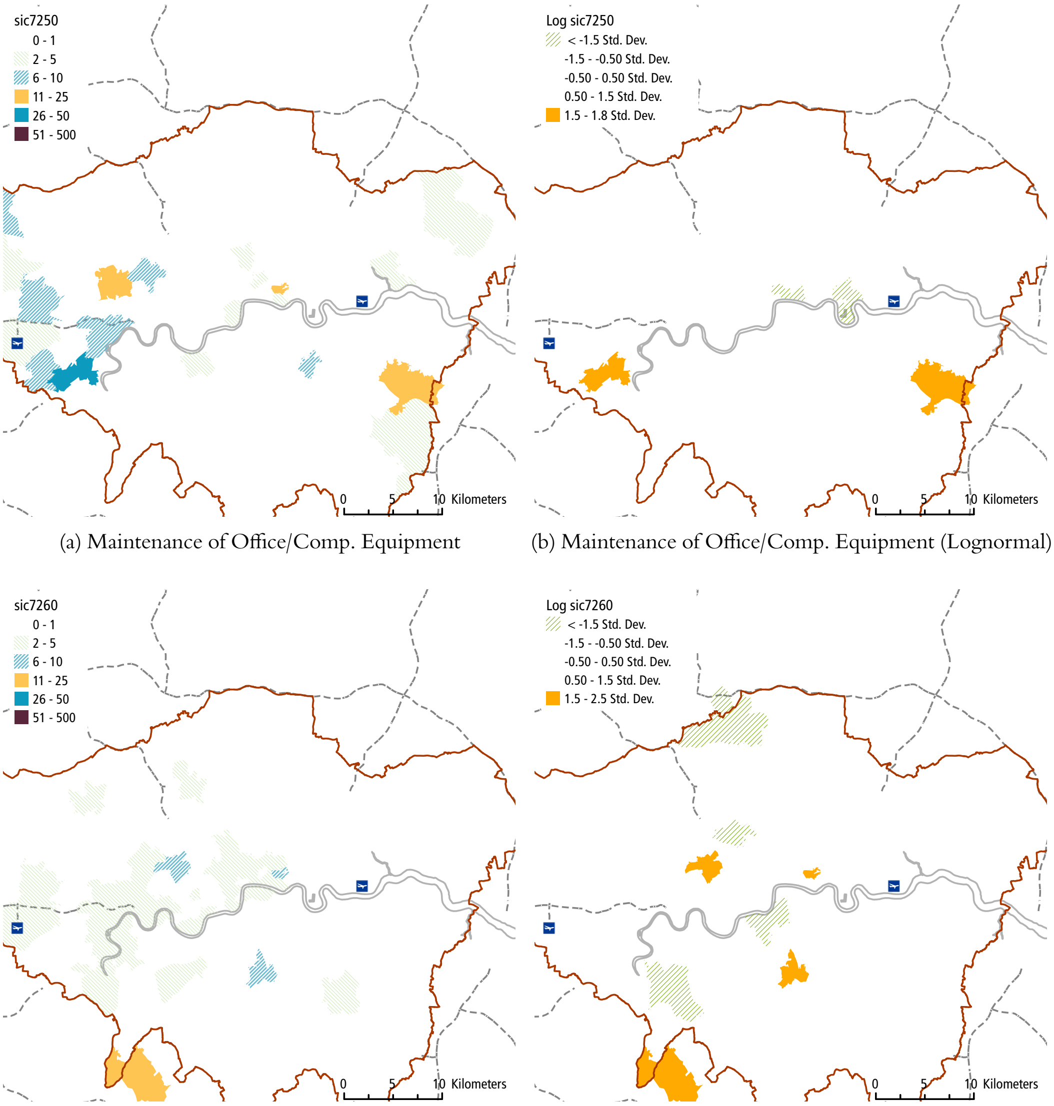
(c) Data Processing

(d) Data Processing (Lognormal)

(e) Data Base Activities

(f) Data Base Activities (Lognormal)

Figure 10.22: London Analytical Group LQs (Part 2)



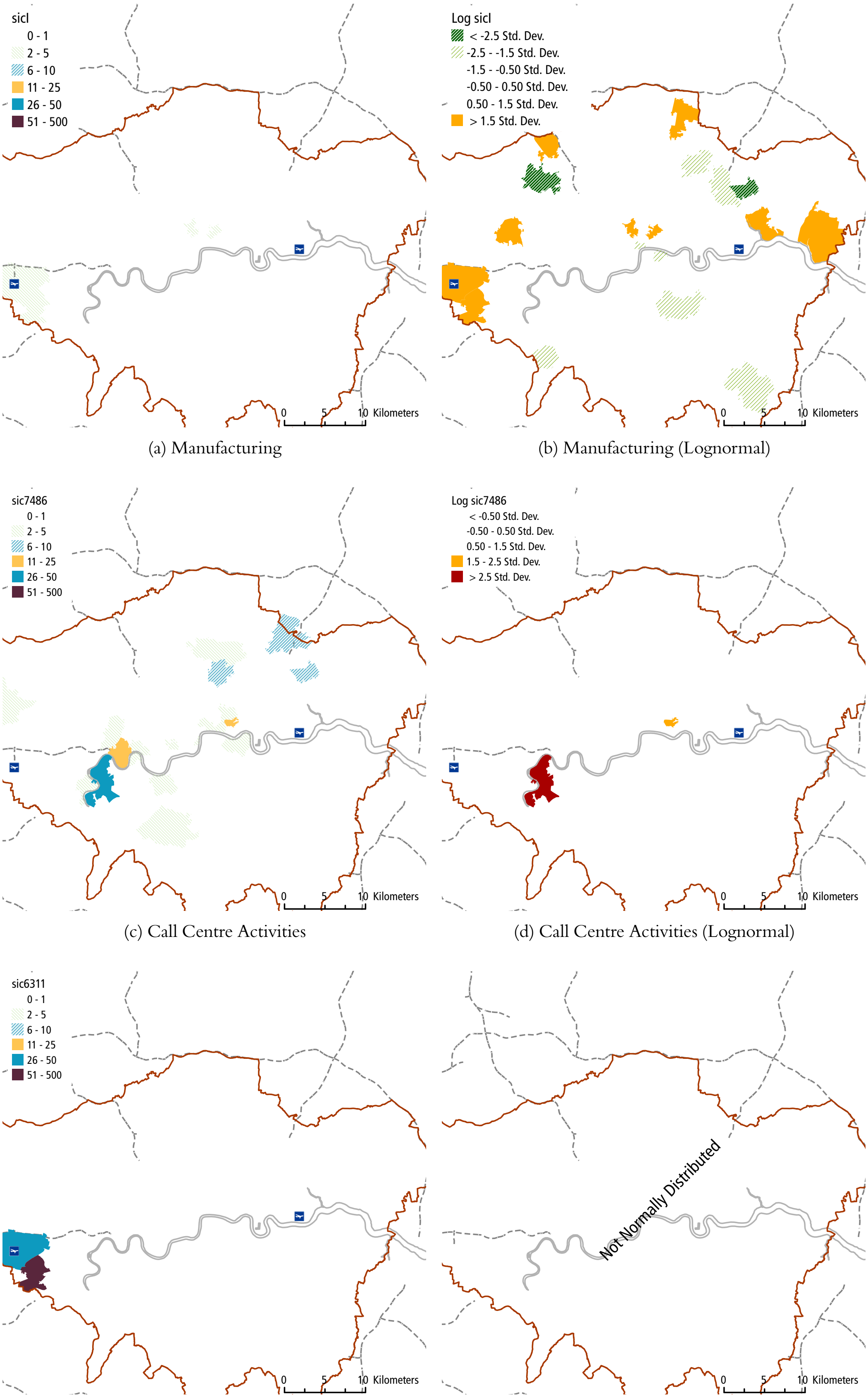
(a) Maintenance of Office/Comp. Equipment

(b) Maintenance of Office/Comp. Equipment (Lognormal)

(c) Other Computer Activity

(d) Other Computer Activity (Lognormal)

Figure 10.23: London Analytical Group LQs (Part 3)



(a) Manufacturing

(b) Manufacturing (Lognormal)

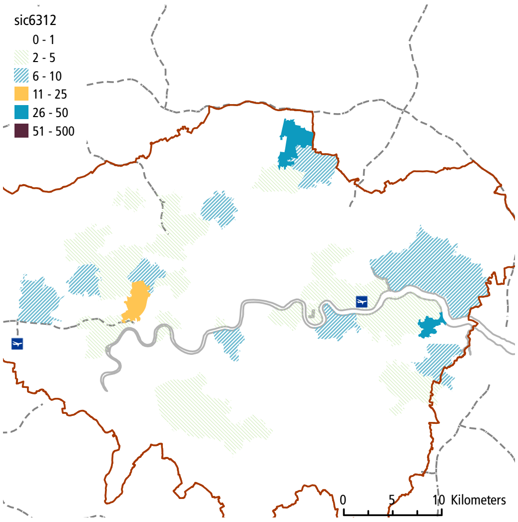
(c) Call Centre Activities

(d) Call Centre Activities (Lognormal)

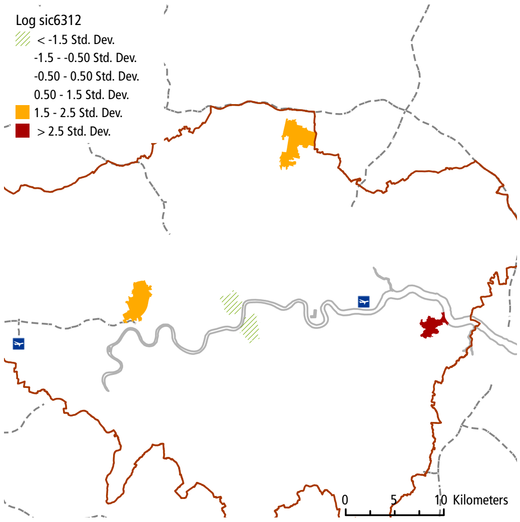
(e) Cargo Handling

(f) Cargo Handling (Lognormal)

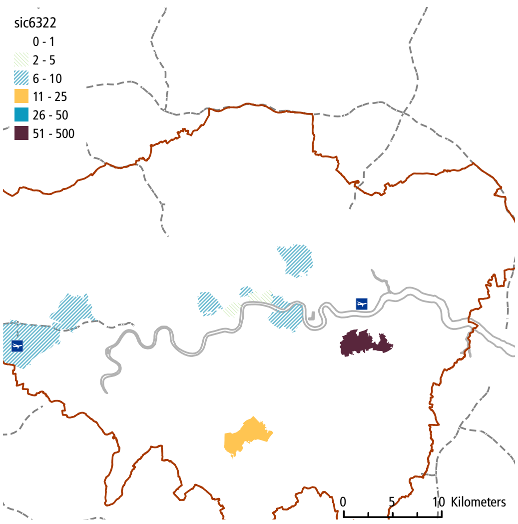
Figure 10.24: London Material & Immaterial Flows LQs (Part 1)



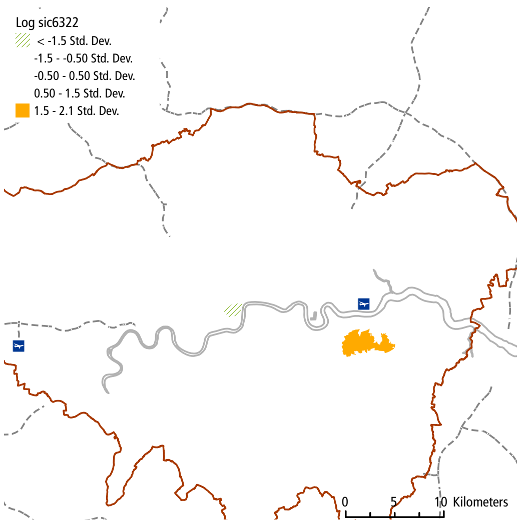
(a) Storage & Warehousing



(b) Storage & Warehousing (Lognormal)



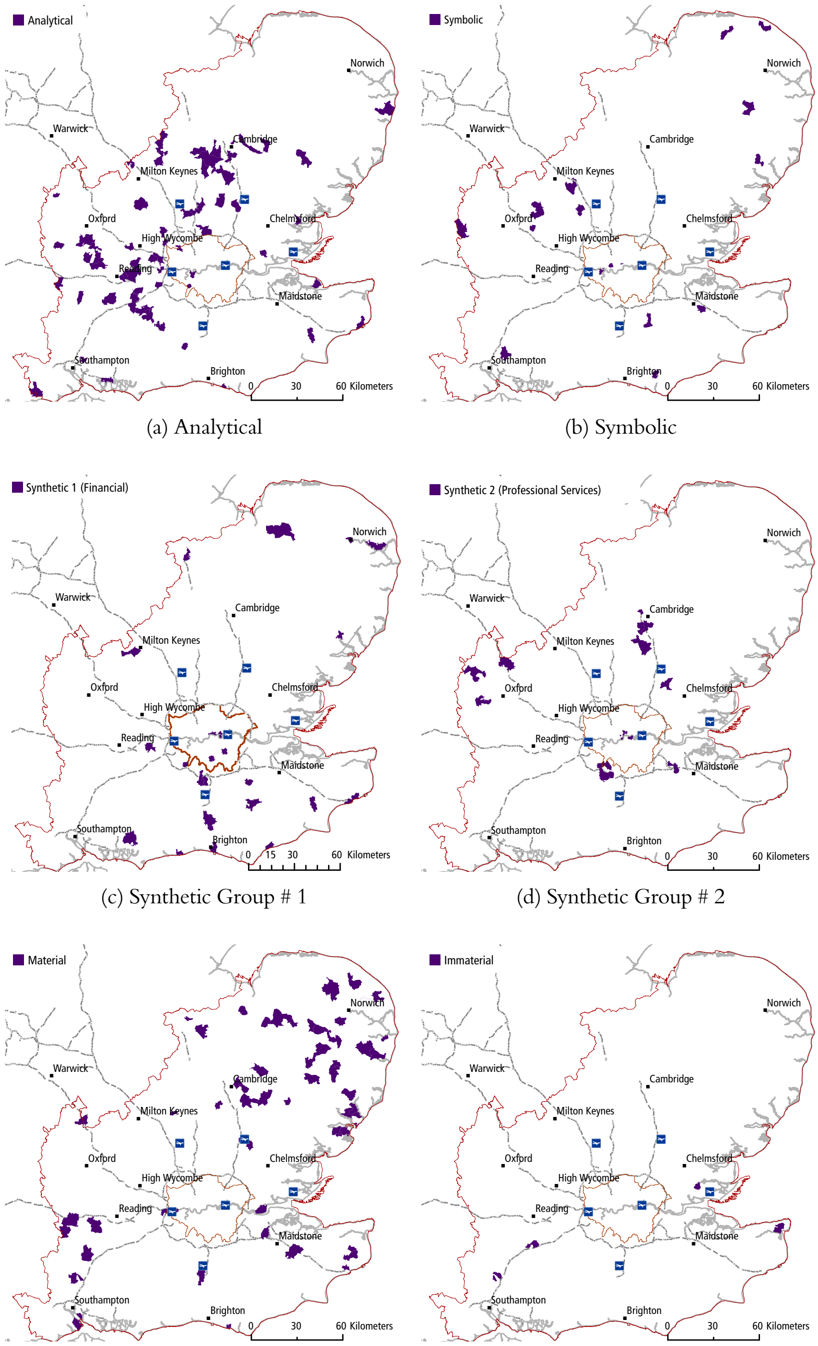
(c) Other Support Water Transport



(d) Other Support Water Transport (Lognormal)

Figure 10.25: London Material & Immaterial Flows LQs (Part 2)

Greater South East of England



(a) Analytical

(b) Symbolic

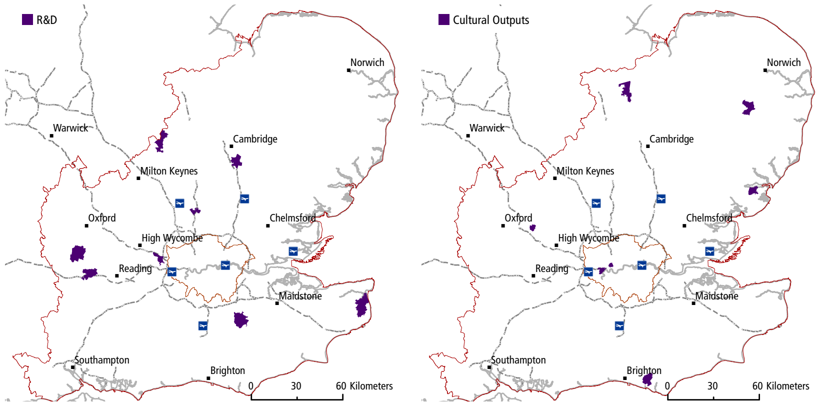
(c) Synthetic Group # 1

(d) Synthetic Group # 2

(e) Material Flows

(f) Immaterial Flows

Figure 10.26: Significant Knowledge Base Locations (Part 1)



(a) R&D (b) Cultural Production

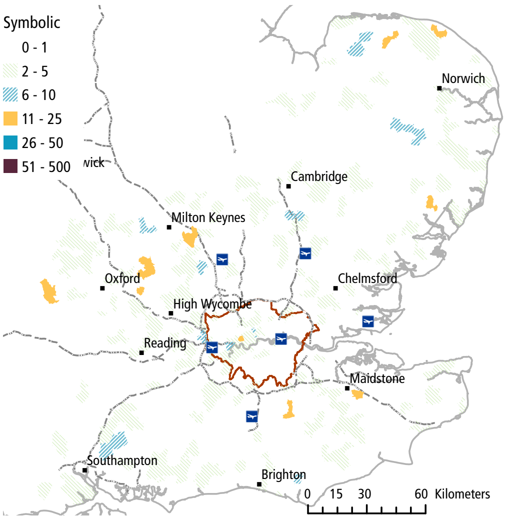
Figure 10.27: Significant NOMIS4 Group Locations

Table 10.6: Lognormal 1-Digit Industries & Knowledge Base Groups in the GSE

Group/SIC Code	p-value	KS Statistic	Critical Value
Synthetic #1	$1.030000e^{-1}$	$2.503114e^{-2}$	$3.521580e^{-2}$
Synthetic #2	$2.000000e^{-3}$	$4.700069e^{-2}$	$4.857349e^{-2}$
Immaterial	$4.860000e^{-1}$	$5.151879e^{-2}$	$1.047665e^{-1}$
SIC CE	$4.230000e^{-1}$	$4.998108e^{-2}$	$1.026058e^{-1}$
SIC I	$3.000000e^{-3}$	$4.251174e^{-2}$	$4.586531e^{-2}$
SIC OPQ	$2.000000e^{-3}$	$3.749822e^{-2}$	$4.098666e^{-2}$

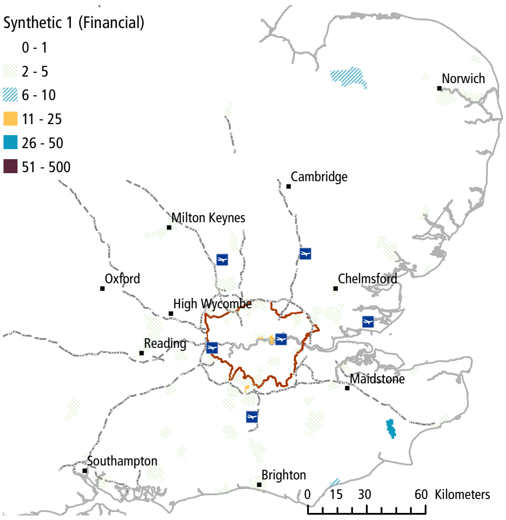
Table 10.7: Lognormal 3-Digit Industries in the GSE

Group/SIC Code	p-value	KS Statistic	Critical Value
Real Estate	$6.070000e^{-1}$	$1.633471e^{-2}$	$3.437133e^{-2}$
APS	$5.100000e^{-2}$	$2.506412e^{-2}$	$3.348447e^{-2}$
SIC 602	$3.330000e^{-1}$	$1.990182e^{-2}$	$3.652165e^{-2}$
SIC 622	$4.000000e^{-3}$	$7.141296e^{-2}$	$7.745951e^{-2}$
SIC 631	$4.900000e^{-2}$	$3.252543e^{-2}$	$4.471442e^{-2}$
SIC 672	$1.060000e^{-1}$	$2.867493e^{-2}$	$4.031588e^{-2}$
SIC 701	$6.590000e^{-1}$	$1.633471e^{-2}$	$3.802105e^{-2}$
SIC 721	$1.320000e^{-1}$	$2.568541e^{-2}$	$3.965083e^{-2}$
SIC 722	$1.500000e^{-2}$	$3.038875e^{-2}$	$3.768211e^{-2}$
SIC 724	$3.000000e^{-3}$	$4.385602e^{-2}$	$4.829530e^{-2}$
SIC 742	$2.400000e^{-2}$	$2.875258e^{-2}$	$3.759085e^{-2}$
SIC 744	$9.400000e^{-2}$	$2.555503e^{-2}$	$3.601911e^{-2}$
SIC 921	$4.200000e^{-1}$	$2.279132e^{-2}$	$4.535059e^{-2}$
SIC 922	$1.120000e^{-1}$	$3.254360e^{-2}$	$4.536390e^{-2}$

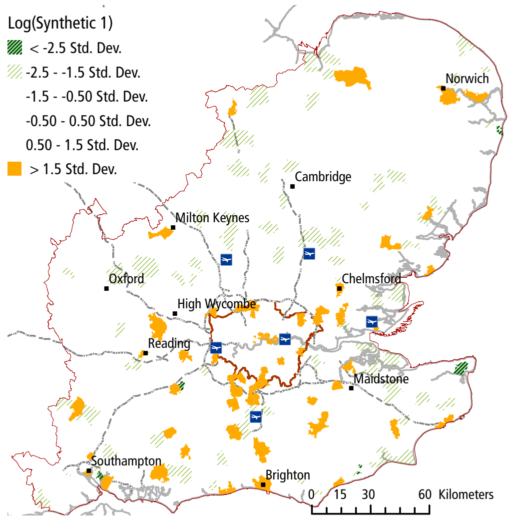


(a) Symbolic Group

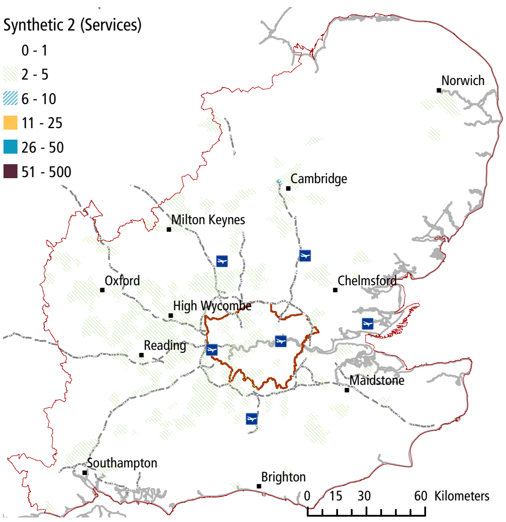
(b) Symbolic Group (Lognormal)



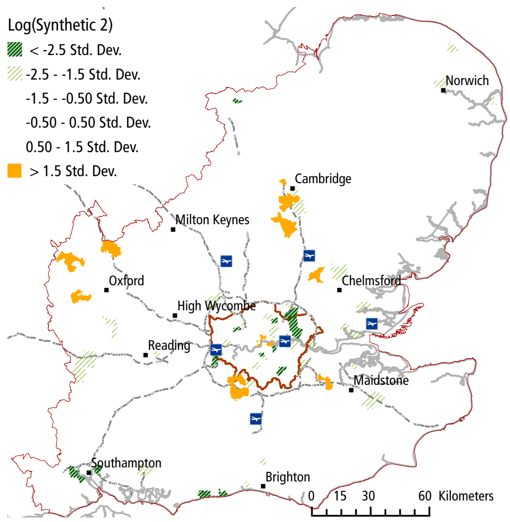
(c) Synthetic Group #1



(d) Synthetic Group #1 (Lognormal)

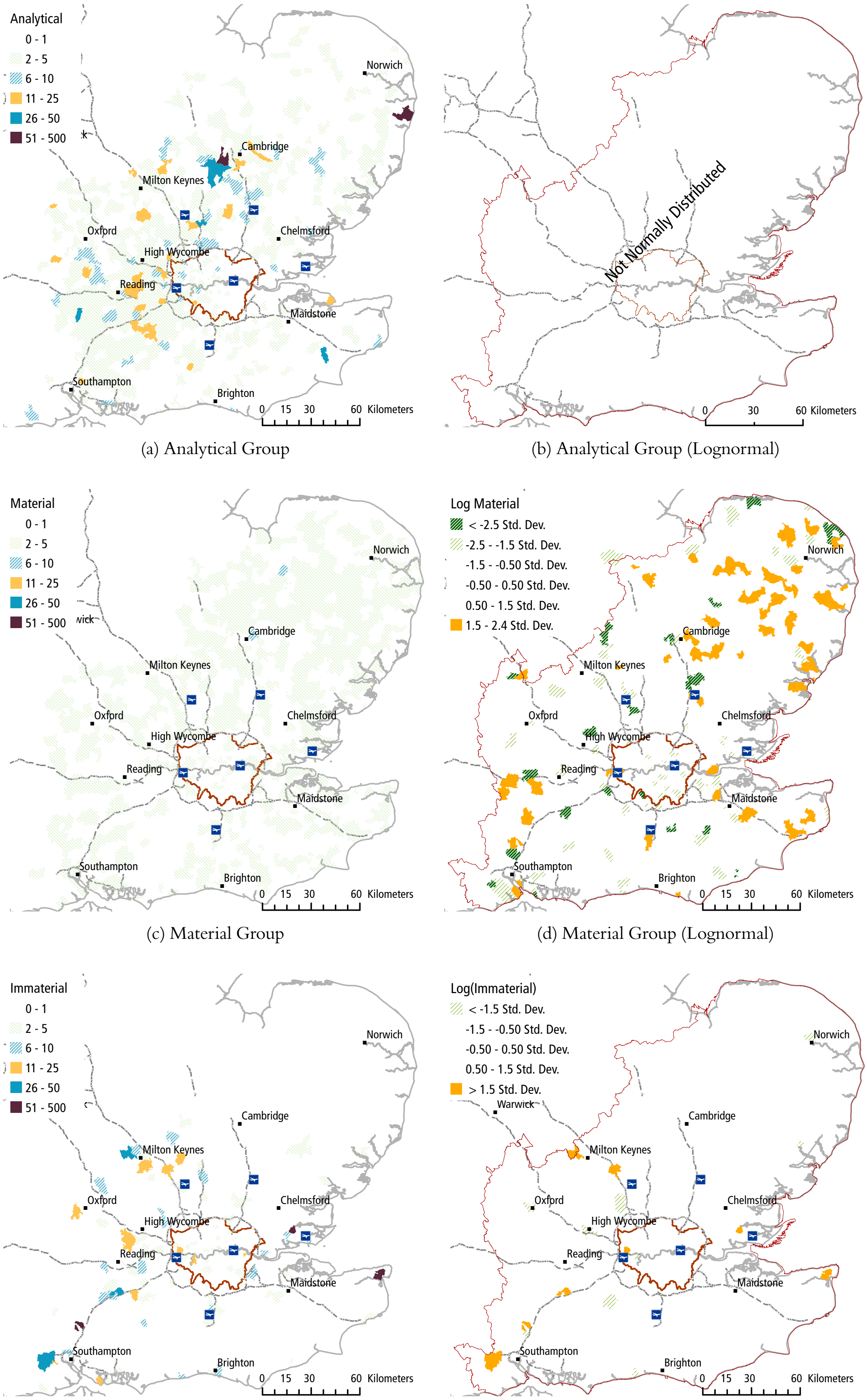


(e) Synthetic Group #2



(f) Synthetic Group #2 (Lognormal)

Figure 10.28: GSE Knowledge Base LQs (Part 1)



(a) Analytical Group

(b) Analytical Group (Lognormal)

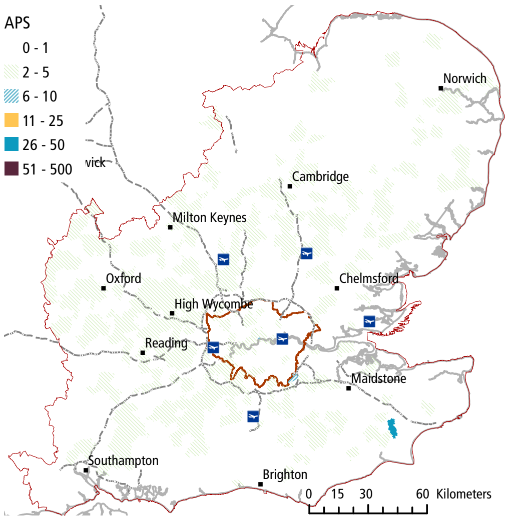
(c) Material Group

(d) Material Group (Lognormal)

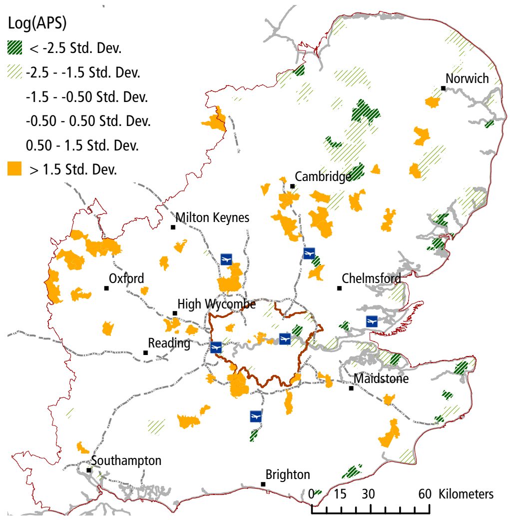
(e) Immaterial Group

(f) Immaterial Group (Lognormal)

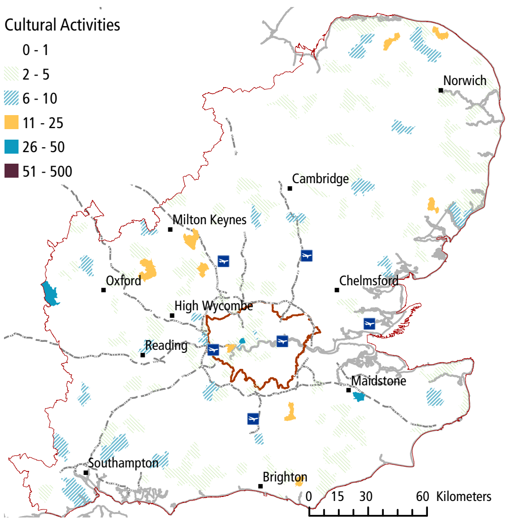
Figure 10.29: GSE Knowledge Base LQs (Part 2)



(a) APS Group



(b) APS Group (Lognormal)



(c) Cultural Activity

(d) Cultural Activity (Lognormal)

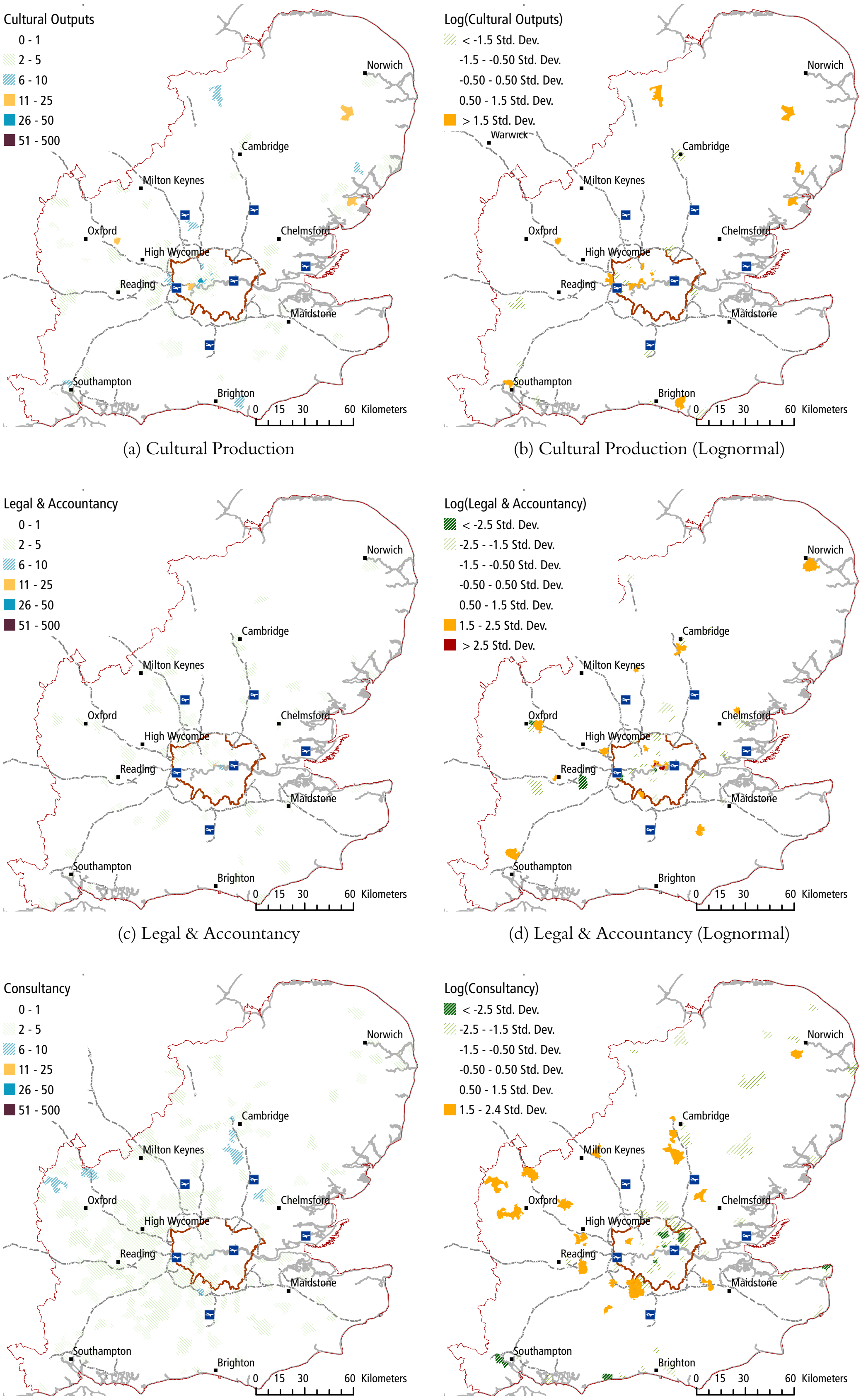
Figure 10.30: GSE NOMIS3 Group LQS

Table 10.8: Lognormal 4-Digit Industries & Groups in the GSE

Group/SIC Code	p-value	KS Statistic	Critical Value
Consulting	$3.000000e^{-3}$	$4.439029e^{-2}$	$4.810723e^{-2}$
Cultural Production	$4.820000e^{-1}$	$3.903307e^{-2}$	$7.367056e^{-2}$
ICT	$9.130000e^{-1}$	$2.097921e^{-2}$	$6.010102e^{-2}$
Legal & Accountancy	$2.200000e^{-2}$	$5.010564e^{-2}$	$6.541148e^{-2}$
Logistics	$9.870000e^{-1}$	$1.664752e^{-2}$	$5.761143e^{-2}$
R&D	$6.230000e^{-1}$	$4.238402e^{-2}$	$1.043883e^{-1}$
SIC 6010	$4.500000e^{-1}$	$6.483955e^{-2}$	$1.212971e^{-1}$
SIC 6024	$5.720000e^{-1}$	$3.300902e^{-2}$	$7.431929e^{-2}$
SIC 6110	$6.680000e^{-1}$	$9.114679e^{-2}$	$2.322158e^{-1}$
SIC 6120	$9.400000e^{-2}$	$3.192235e^{-1}$	$4.398551e^{-1}$
SIC 6210	$2.020000e^{-1}$	$1.288911e^{-1}$	$2.070321e^{-1}$
SIC 6220	$3.560000e^{-1}$	$1.226963e^{-1}$	$2.330035e^{-1}$
SIC 6311	$7.210000e^{-1}$	$1.247214e^{-1}$	$2.901943e^{-1}$
SIC 6312	$6.080000e^{-1}$	$3.948611e^{-2}$	$8.086131e^{-2}$
SIC 6321	$2.660000e^{-1}$	$6.237601e^{-2}$	$1.152741e^{-1}$
SIC 6322	$5.630000e^{-1}$	$9.028561e^{-2}$	$1.913377e^{-1}$
SIC 6323	$5.780000e^{-1}$	$9.348754e^{-2}$	$1.950767e^{-1}$
SIC 6512	$4.000000e^{-3}$	$5.544093e^{-2}$	$6.174906e^{-2}$
SIC 6521	$8.690000e^{-1}$	$8.139232e^{-2}$	$2.141980e^{-1}$
SIC 6522	$1.500000e^{-1}$	$7.953625e^{-2}$	$1.315163e^{-1}$
SIC 6523	$2.460000e^{-1}$	$8.724339e^{-2}$	$1.421684e^{-1}$
SIC 6601	$9.190000e^{-1}$	$4.837216e^{-2}$	$1.333251e^{-1}$
SIC 6603	$5.770000e^{-1}$	$5.152301e^{-2}$	$1.052205e^{-1}$
SIC 6711	$9.040000e^{-1}$	$1.301443e^{-1}$	$3.463151e^{-1}$
SIC 6712	$4.000000e^{-2}$	$1.131552e^{-1}$	$1.557341e^{-1}$
SIC 6713	$4.940000e^{-1}$	$5.489040e^{-2}$	$1.146941e^{-1}$
SIC 6720	$3.680000e^{-1}$	$4.531500e^{-2}$	$8.799322e^{-2}$

Table 10.9: Lognormal 4-Digit Industries & Groups in the GSE (cont'd)

Group/SIC Code	p-value	KS Statistic	Critical Value
SIC 7011	$9.520000e^{-1}$	$3.357939e^{-2}$	$9.612657e^{-2}$
SIC 7012	$7.710000e^{-1}$	$1.989858e^{-1}$	$4.377425e^{-1}$
SIC 7020	$3.110000e^{-1}$	$3.935506e^{-2}$	$7.115581e^{-2}$
SIC 7031	$4.810000e^{-1}$	$3.719805e^{-2}$	$7.545935e^{-2}$
SIC 7032	$4.760000e^{-1}$	$4.693015e^{-2}$	$1.001833e^{-1}$
SIC 7210	$4.200000e^{-2}$	$1.290204e^{-1}$	$1.614223e^{-1}$
SIC 7221	$6.700000e^{-2}$	$1.322646e^{-1}$	$1.831364e^{-1}$
SIC 7222	$9.590000e^{-1}$	$2.047058e^{-2}$	$5.589011e^{-2}$
SIC 7230	$4.990000e^{-1}$	$6.170311e^{-2}$	$1.269062e^{-1}$
SIC 7240	$6.660000e^{-1}$	$8.141909e^{-2}$	$1.778349e^{-1}$
SIC 7250	$5.160000e^{-1}$	$6.719156e^{-2}$	$1.370943e^{-1}$
SIC 7260	$7.660000e^{-1}$	$3.820546e^{-2}$	$9.750981e^{-2}$
SIC 7310	$6.070000e^{-1}$	$4.238402e^{-2}$	$9.908797e^{-2}$
SIC 7320	$2.390000e^{-1}$	$1.552222e^{-1}$	$2.500024e^{-1}$
SIC 7411	$9.000000e^{-3}$	$6.279647e^{-2}$	$7.435034e^{-2}$
SIC 7413	$7.020000e^{-1}$	$5.106149e^{-2}$	$1.048781e^{-1}$
SIC 7414	$9.000000e^{-3}$	$4.847530e^{-2}$	$5.142793e^{-2}$
SIC 7415	$2.670000e^{-1}$	$4.797992e^{-2}$	$8.261917e^{-2}$
SIC 7420	$9.710000e^{-1}$	$1.847552e^{-2}$	$5.601301e^{-2}$
SIC 7440	$1.810000e^{-1}$	$6.148063e^{-2}$	$1.043173e^{-1}$
SIC 7486	$7.100000e^{-2}$	$1.082492e^{-1}$	$1.631336e^{-1}$
SIC 7487	$1.500000e^{-1}$	$3.217314e^{-2}$	$5.006915e^{-2}$
SIC 9211	$3.320000e^{-1}$	$8.201646e^{-2}$	$1.403197e^{-1}$
SIC 9212	$6.600000e^{-2}$	$1.846600e^{-1}$	$2.574694e^{-1}$
SIC 9213	$5.150000e^{-1}$	$6.522641e^{-2}$	$1.280097e^{-1}$
SIC 9220	$7.500000e^{-1}$	$5.738069e^{-2}$	$1.402929e^{-1}$
SIC 9231	$2.180000e^{-1}$	$6.991280e^{-2}$	$1.123478e^{-1}$
SIC 9232	$8.580000e^{-1}$	$6.888086e^{-2}$	$1.849424e^{-1}$
SIC 9234	$2.000000e^{-3}$	$2.561040e^{-1}$	$2.592008e^{-1}$



(a) Cultural Production

(b) Cultural Production (Lognormal)

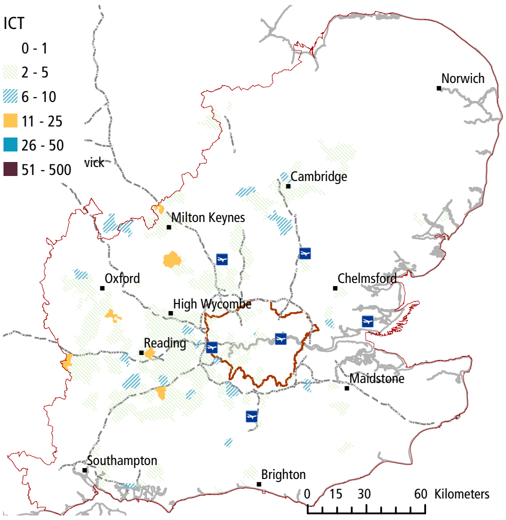
(c) Legal & Accountancy

(d) Legal & Accountancy (Lognormal)

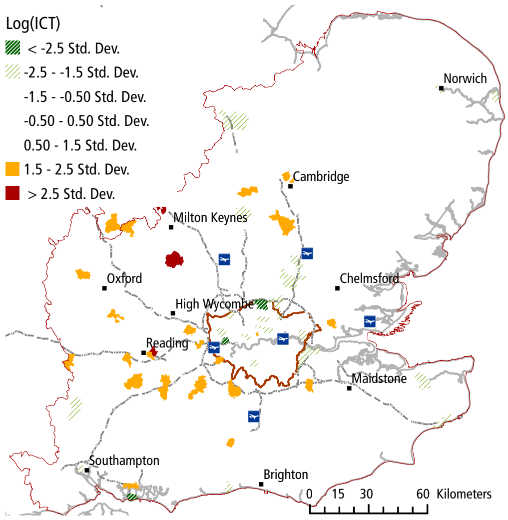
(e) Consulting

(f) Consulting (Lognormal)

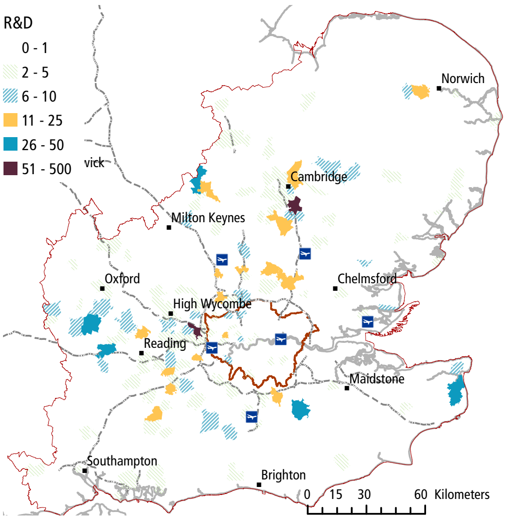
Figure 10.31: GSE NOMIS4 Group LQs (Part 1)



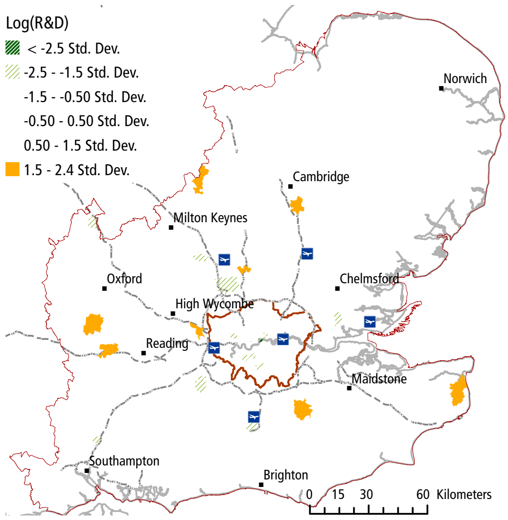
(a) ICT



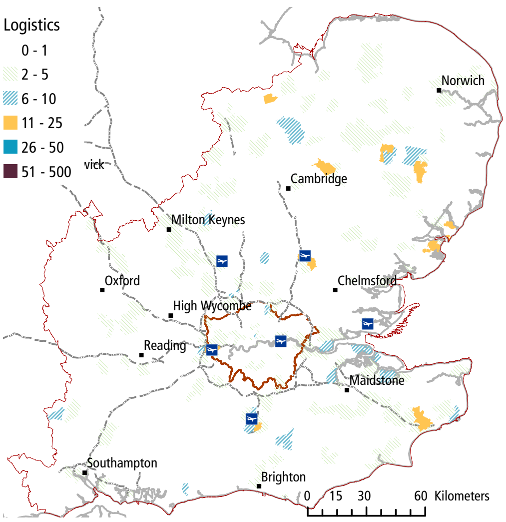
(b) ICT (Lognormal)



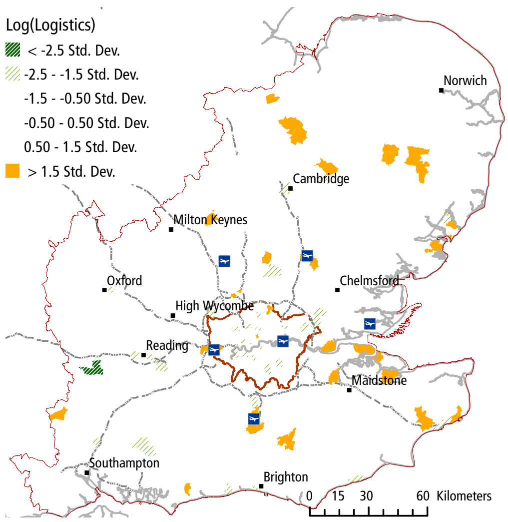
(c) R&D



(d) R&D (Lognormal)

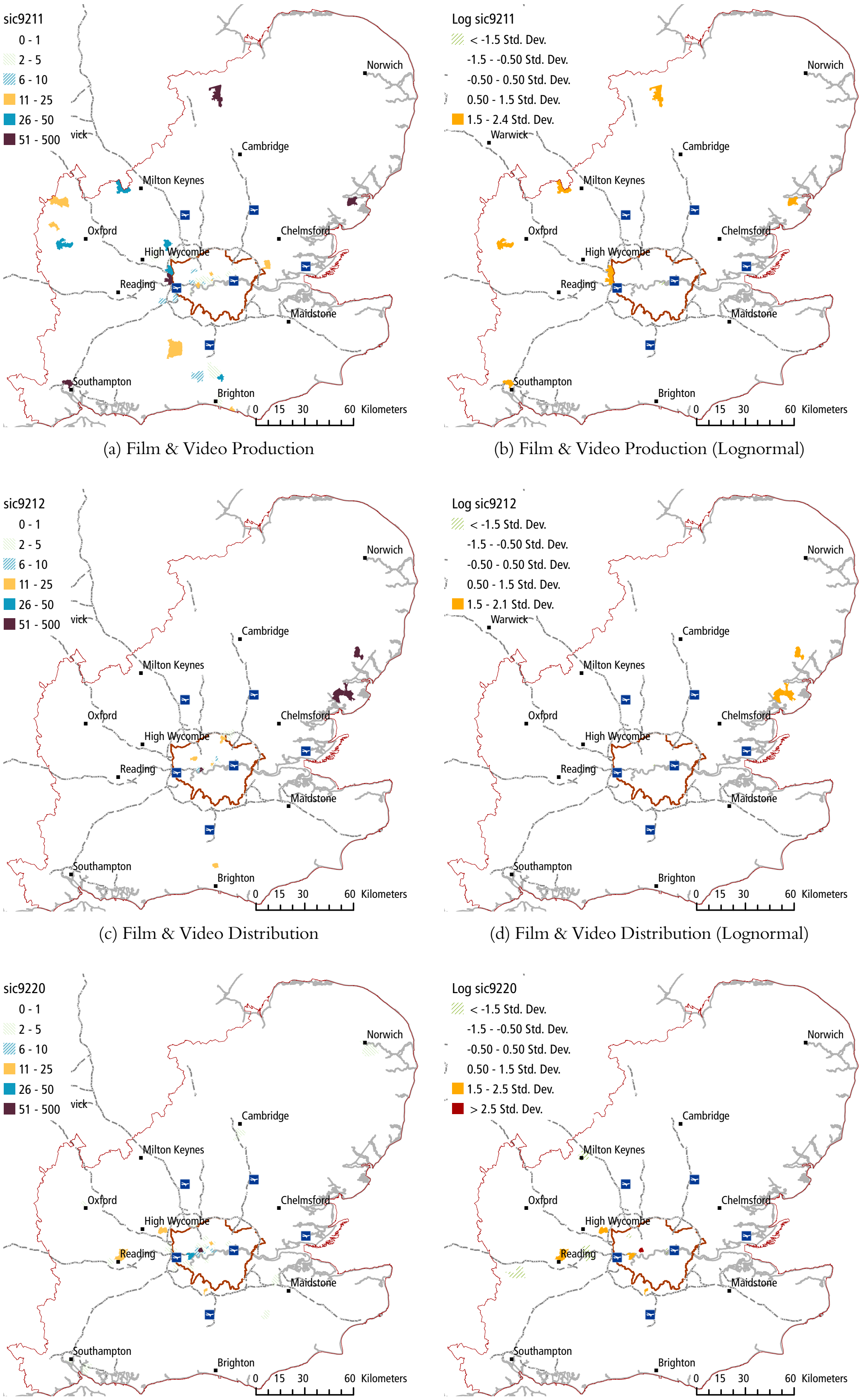


(e) Logistics



(f) Logistics (Lognormal)

Figure 10.32: GSE NOMIS4 Group LQs (Part 2)



(a) Film & Video Production

(b) Film & Video Production (Lognormal)

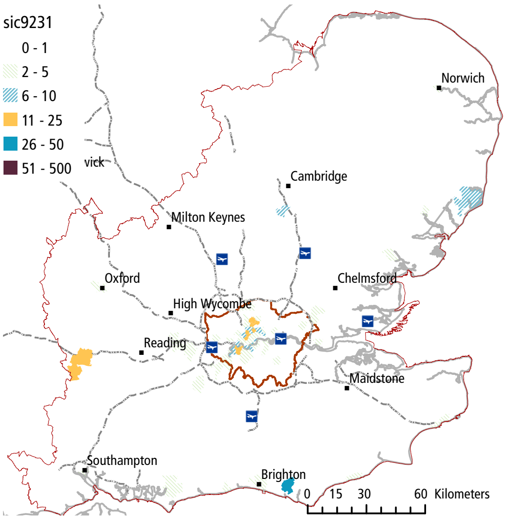
(c) Film & Video Distribution

(d) Film & Video Distribution (Lognormal)

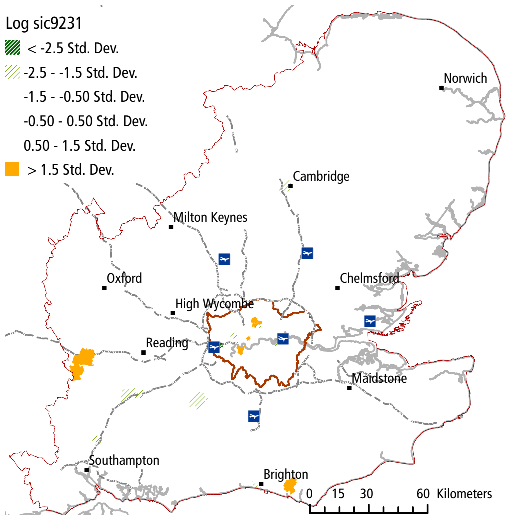
(e) Radio & TV

(f) Radio & TV (Lognormal)

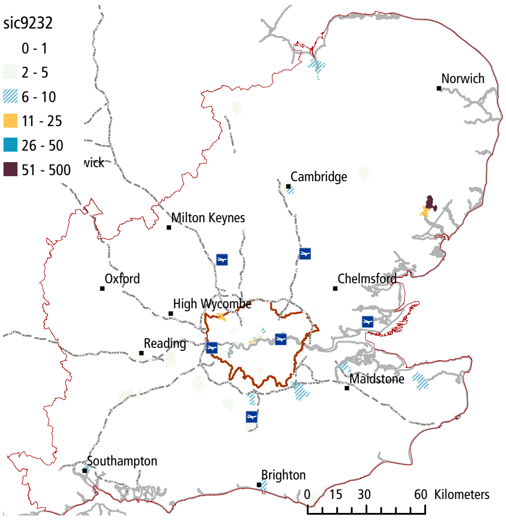
Figure 10.33: GSE Symbolic LQs (Part 1)



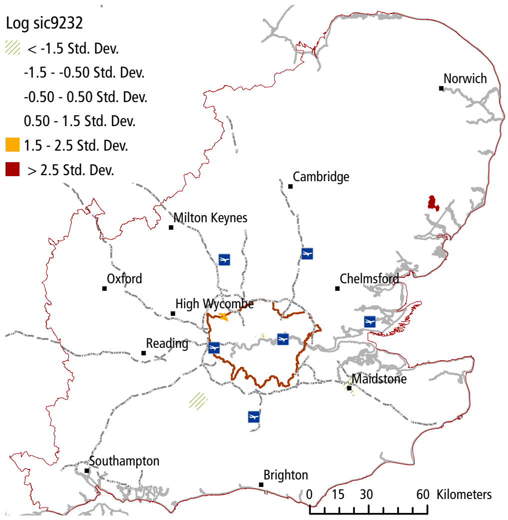
(a) Artistic & Literary



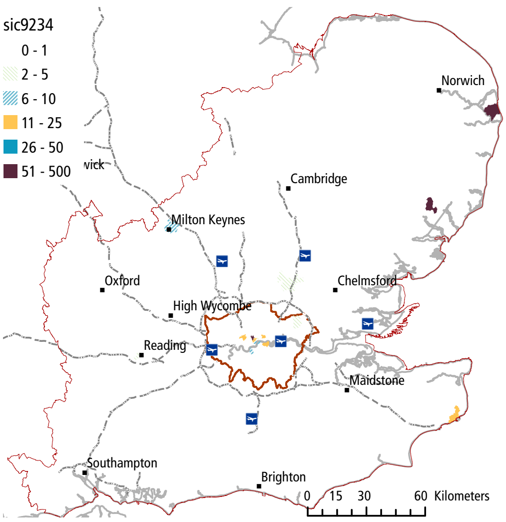
(b) Artistic & Literary (Lognormal)



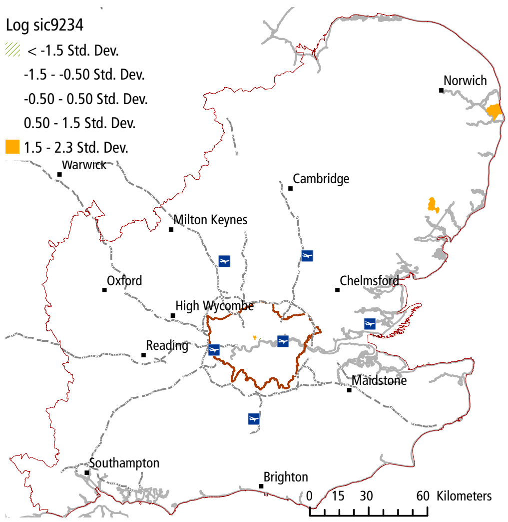
(c) Artistic & Literary



(d) Artistic & Literary (Lognormal)

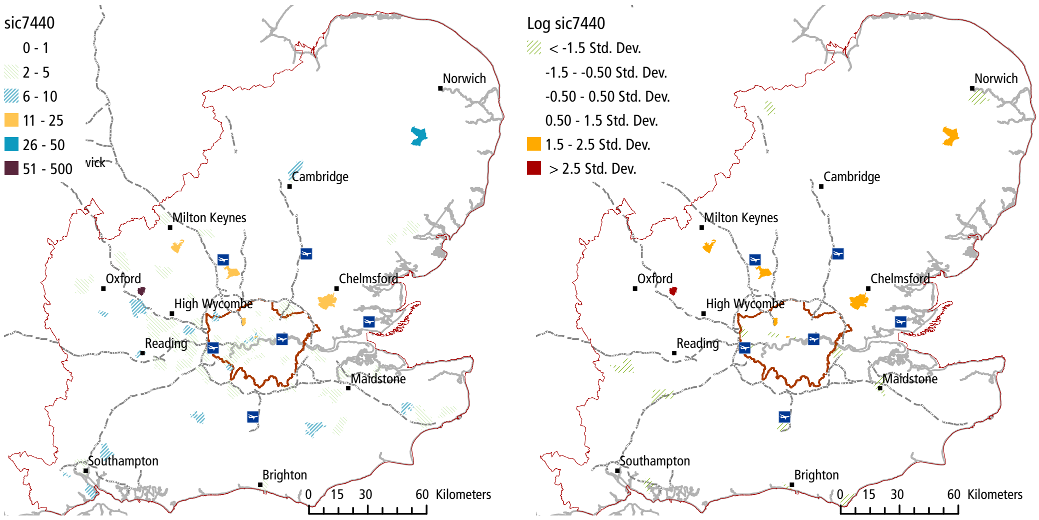


(e) Artistic & Literary



(f) Artistic & Literary (Lognormal)

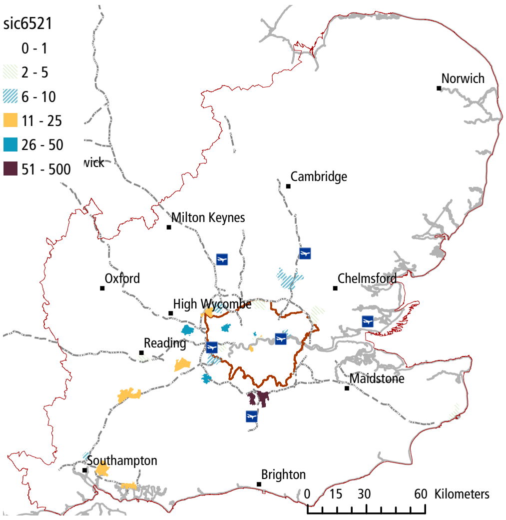
Figure 10.34: GSE Symbolic LQs (Part 2)



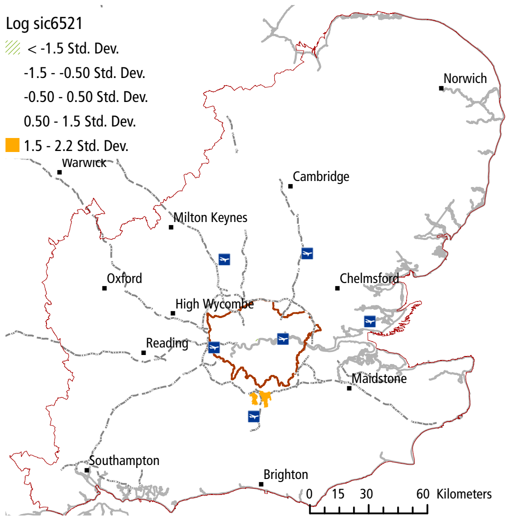
(a) Advertising

(b) Advertising (Lognormal)

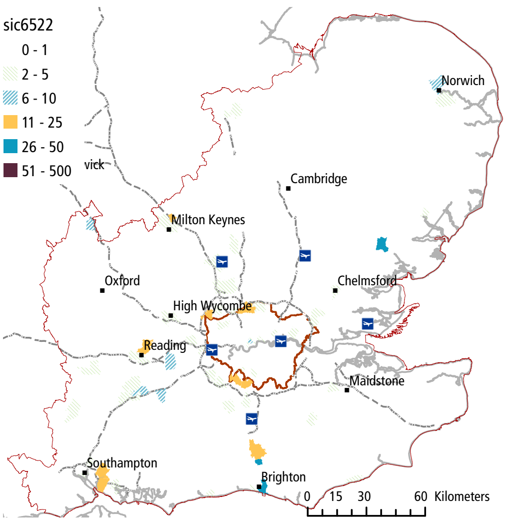
Figure 10.35: GSE Symbolic LQs (Part 3)



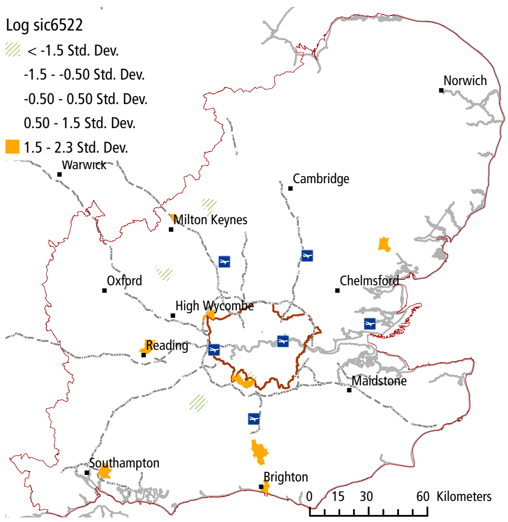
(a) Financial Leasing



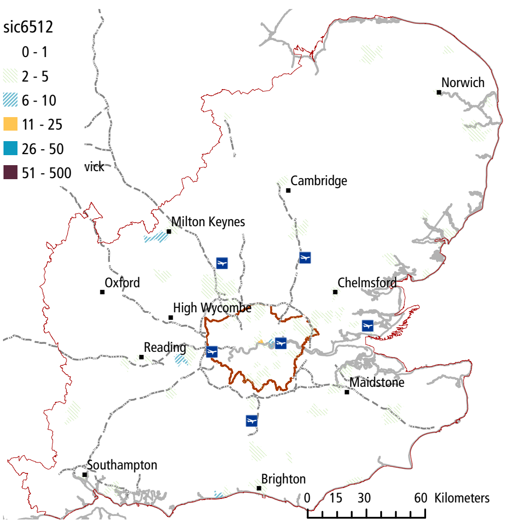
(b) Financial Leasing (Lognormal)



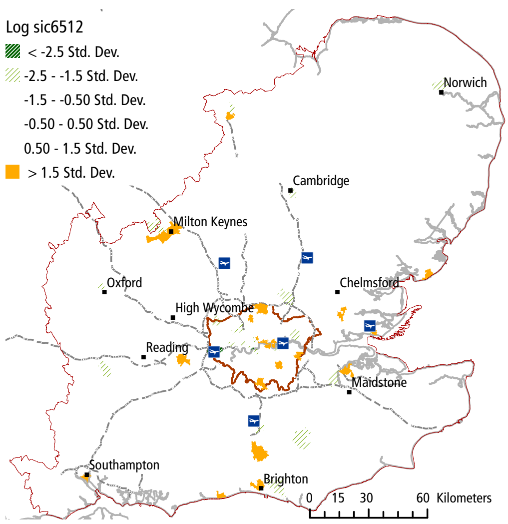
(c) Other Credit Granting



(d) Other Credit Granting (Lognormal)

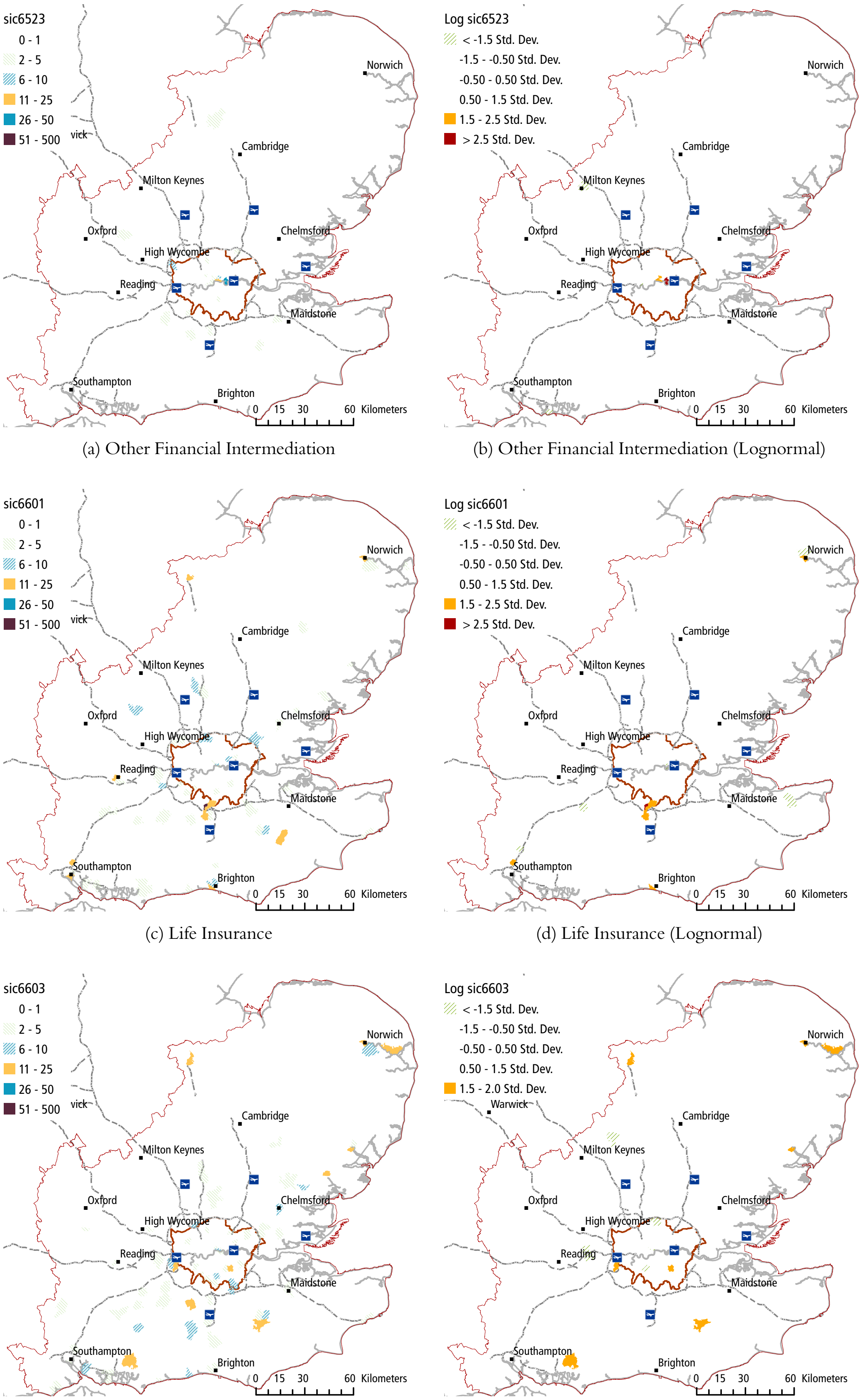


(e) Other Monetary Intermediation



(f) Other Monetary Intermediation (Lognormal)

Figure 10.36: GSE Synthetic Group #1 LQs (Part 1)



(a) Other Financial Intermediation

(b) Other Financial Intermediation (Lognormal)

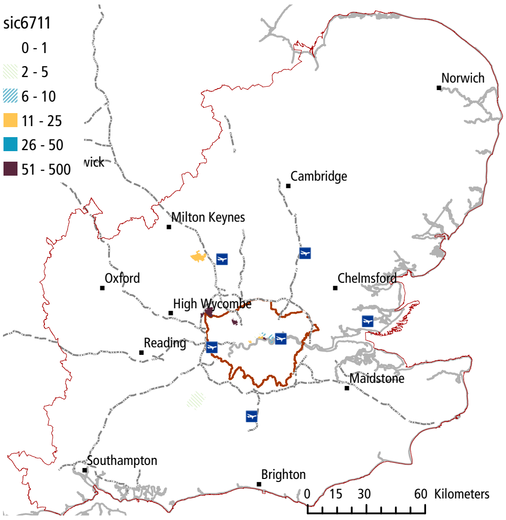
(c) Life Insurance

(d) Life Insurance (Lognormal)

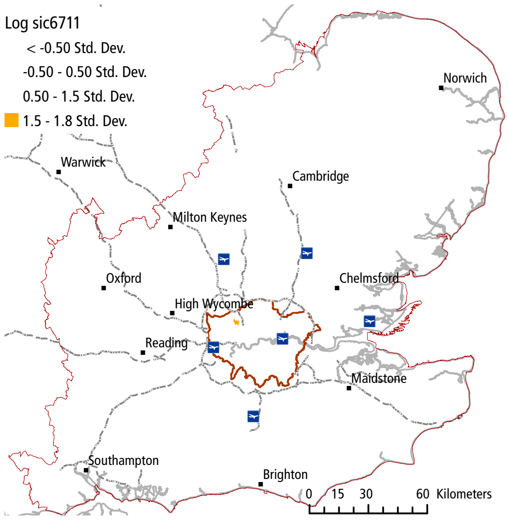
(e) Non-Life Insurance

(f) Non-Life Insurance (Lognormal)

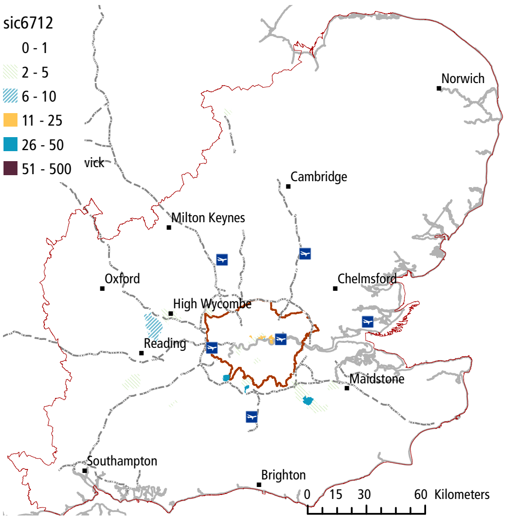
Figure 10.37: GSE Synthetic Group #1 LQs (Part 2)



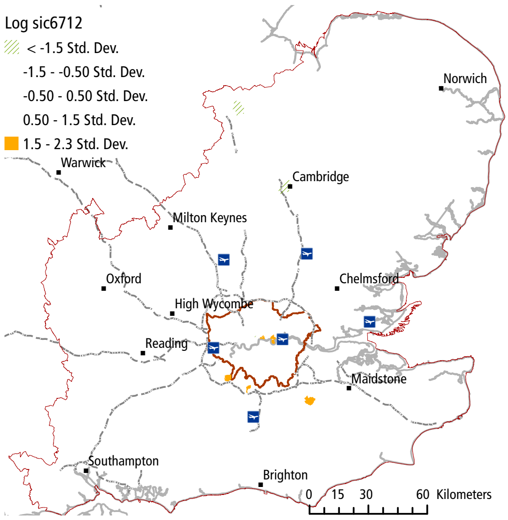
(a) Administration of Financial Markets



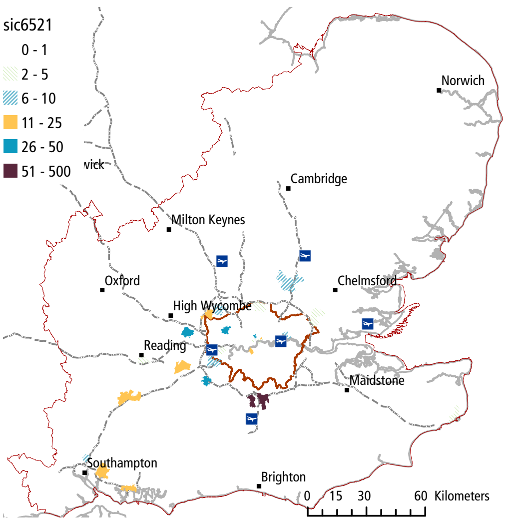
(b) Administration of Financial Markets (Lognormal)



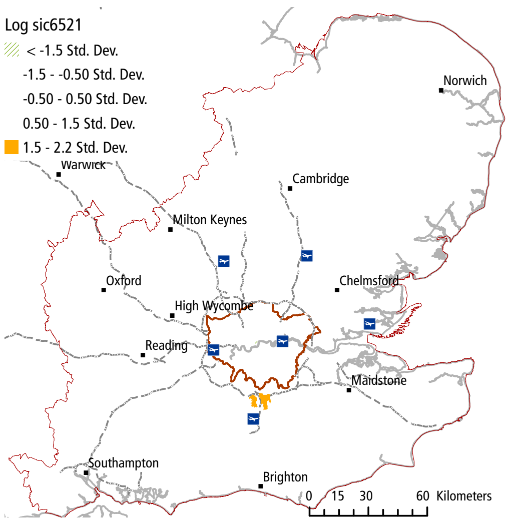
(c) Brokering & Fund Management



(d) Brokering & Fund Management (Lognormal)

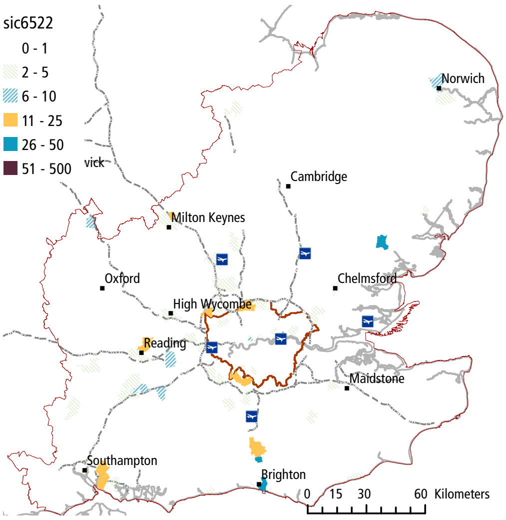


(e) Financial Leasing

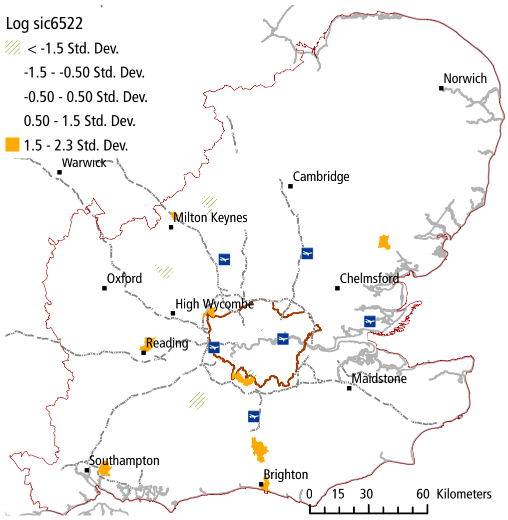


(f) Financial Leasing (Lognormal)

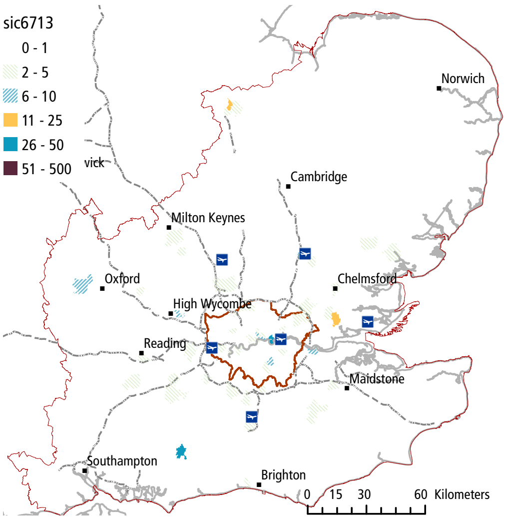
Figure 10.38: GSE Synthetic Group #1 LQs (Part 3)



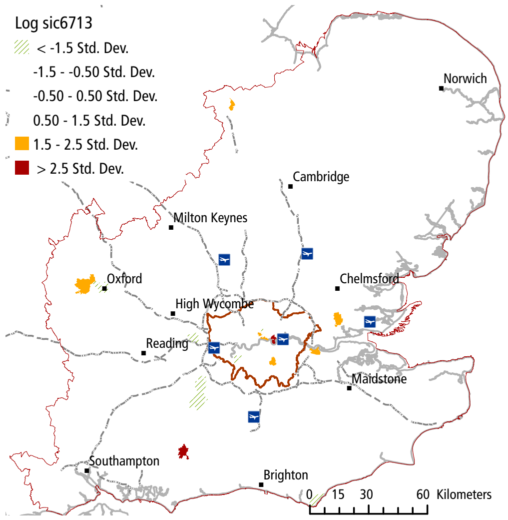
(a) Other Credit Granting



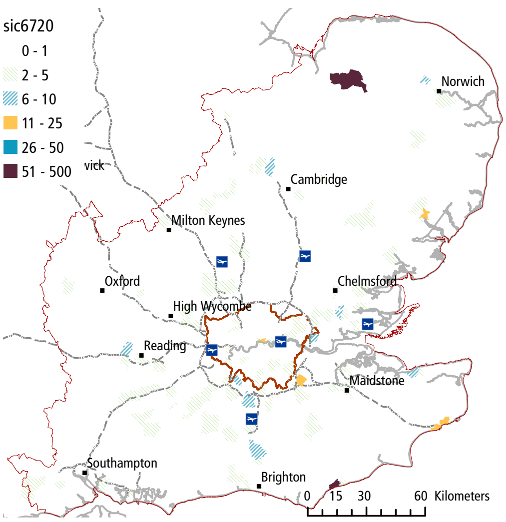
(b) Other Credit Granting (Lognormal)



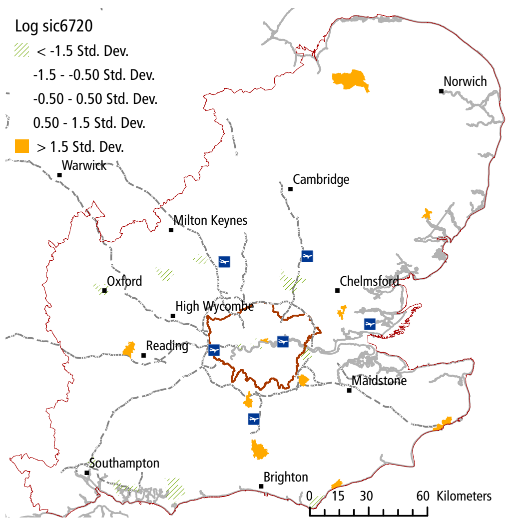
(c) Financial Intermediation Auxiliary



(d) Financial Intermediation Auxiliary (Lognormal)

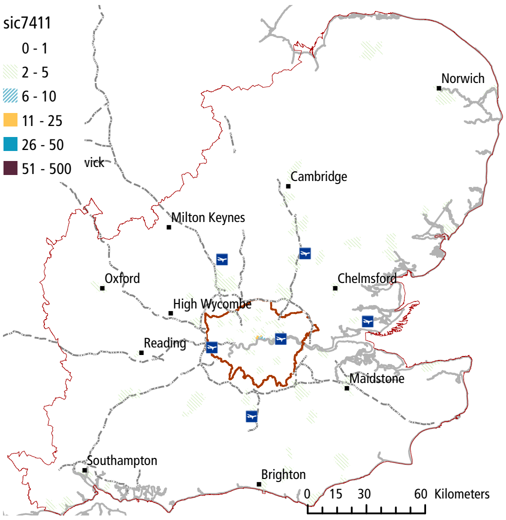


(e) Insurance Auxiliary



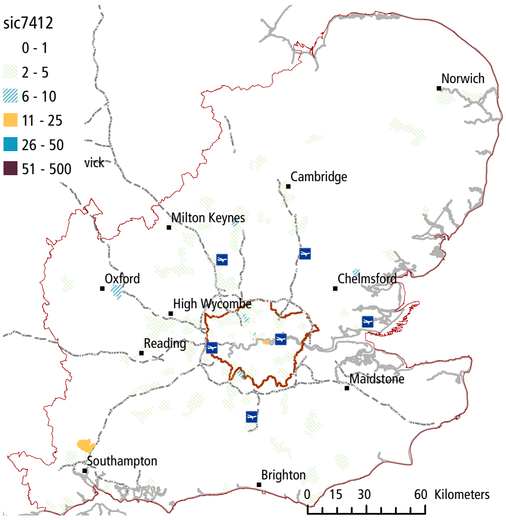
(f) Insurance Auxiliary (Lognormal)

Figure 10.39: GSE Synthetic Group #1 LQs (Part 4)



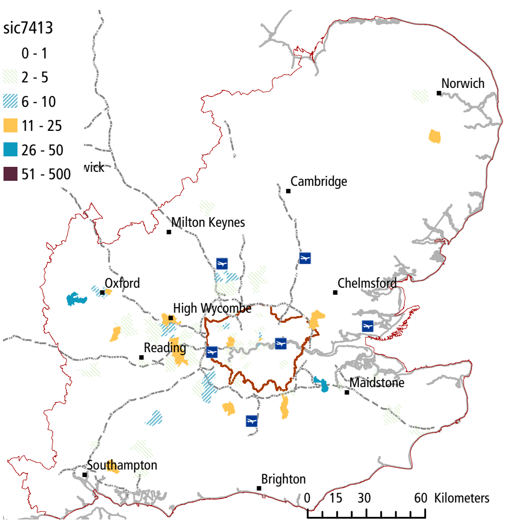
(a) Legal

(b) Legal (Lognormal)

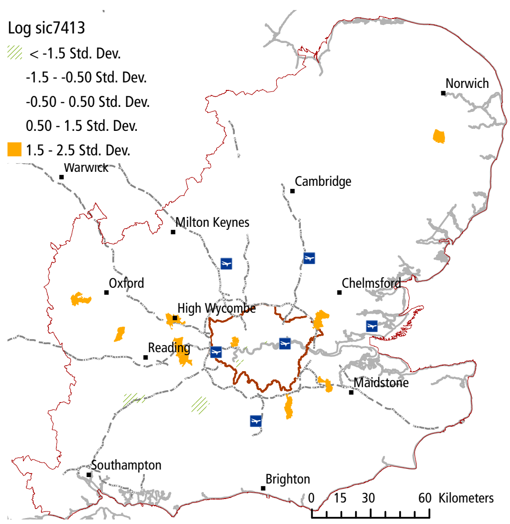


(c) Accountancy

(d) Accountancy (Lognormal)

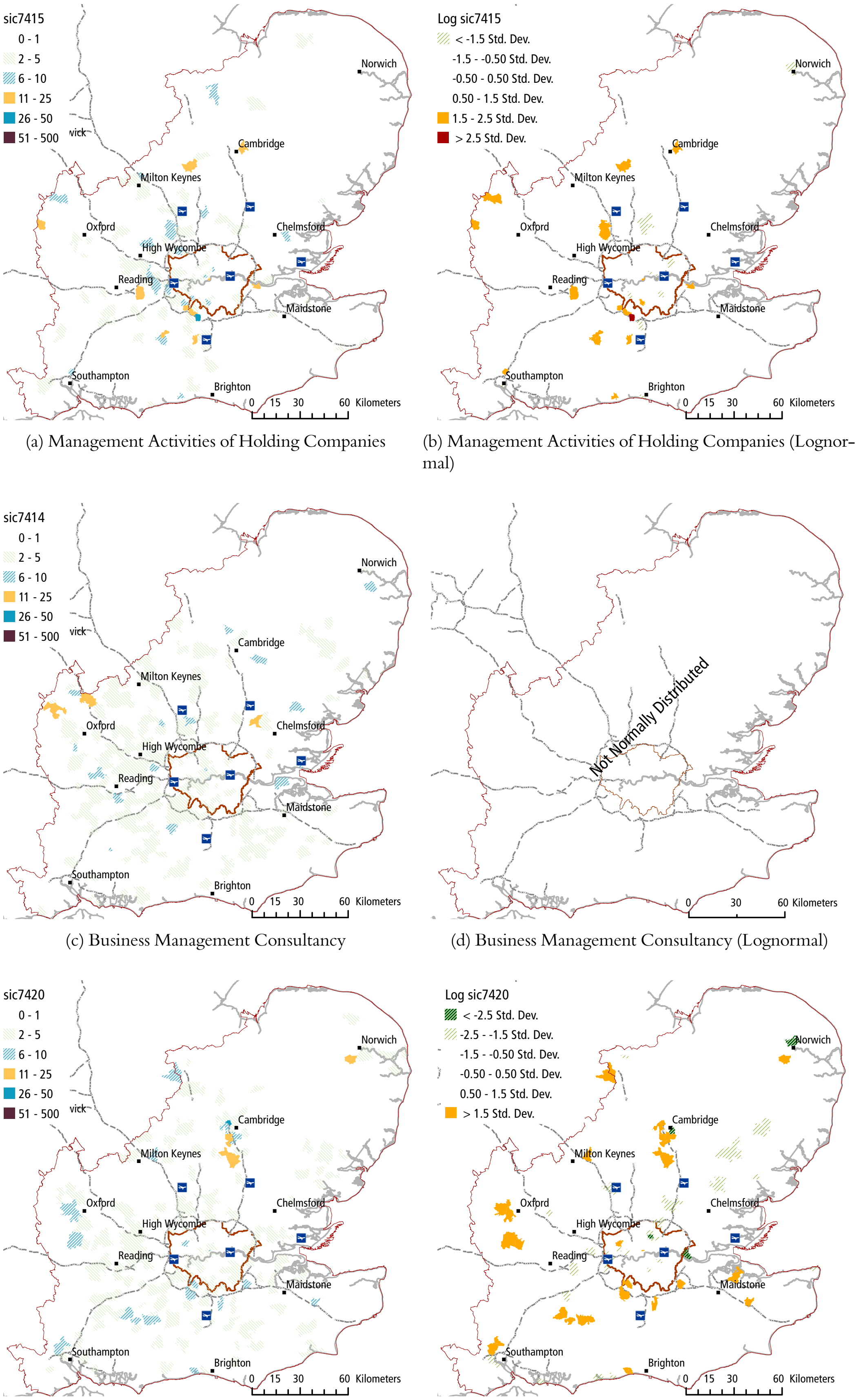


(e) Market Research



(f) Market Research (Lognormal)

Figure 10.40: GSE Synthetic Group #2 LQs (Part 1)



(a) Management Activities of Holding Companies

(b) Management Activities of Holding Companies (Lognormal)

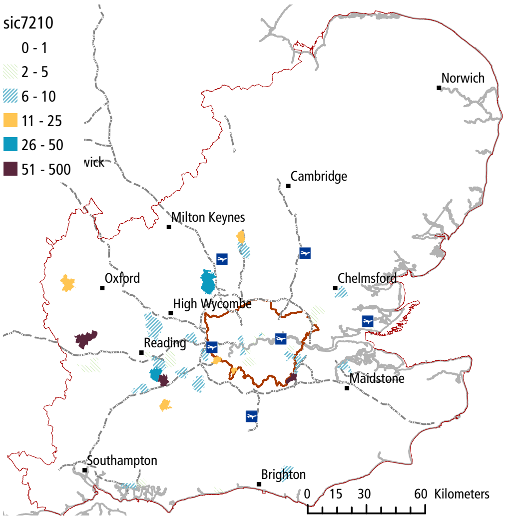
(c) Business Management Consultancy

(d) Business Management Consultancy (Lognormal)

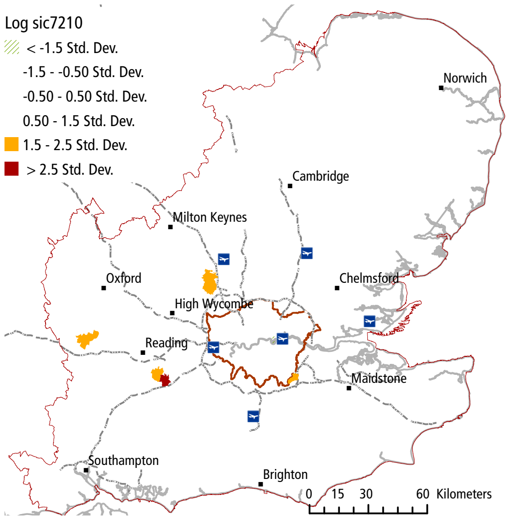
(e) Architecture & Engineering

(f) Architecture & Engineering (Lognormal)

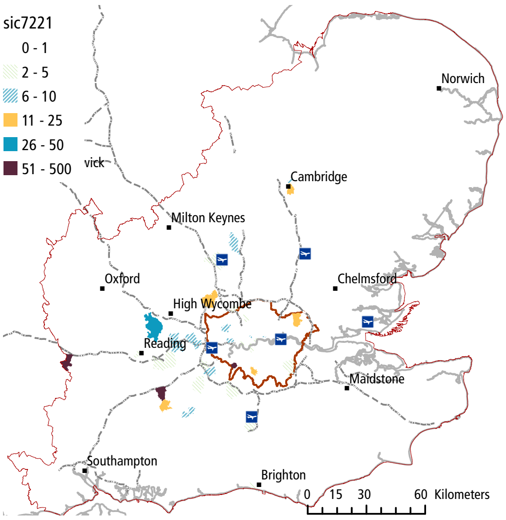
Figure 10.41: GSE Synthetic Group #2 LQs (Part 2)



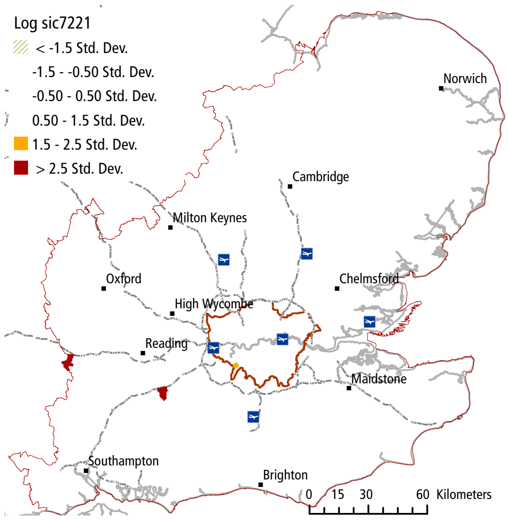
(a) Hardware Consultancy



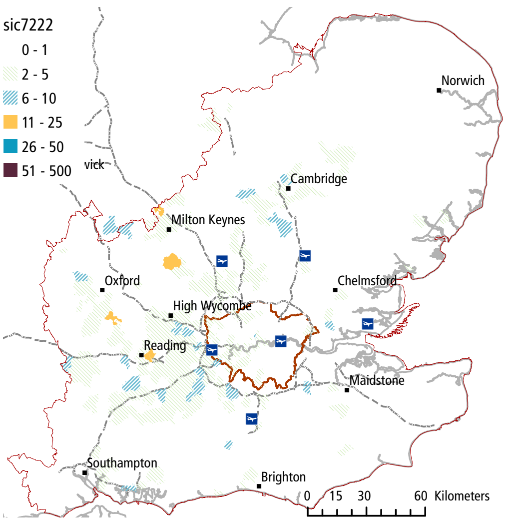
(b) Hardware Consultancy (Lognormal)



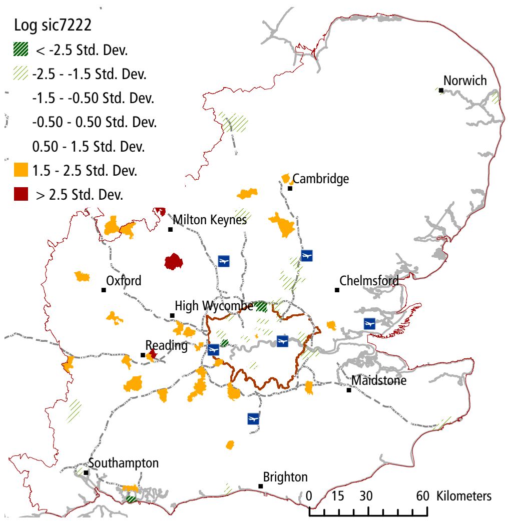
(c) Software Publishing



(d) Software Publishing (Lognormal)

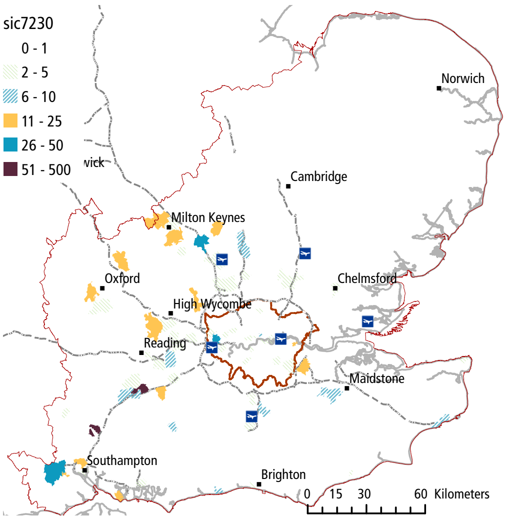


(e) Other Software Consultancy

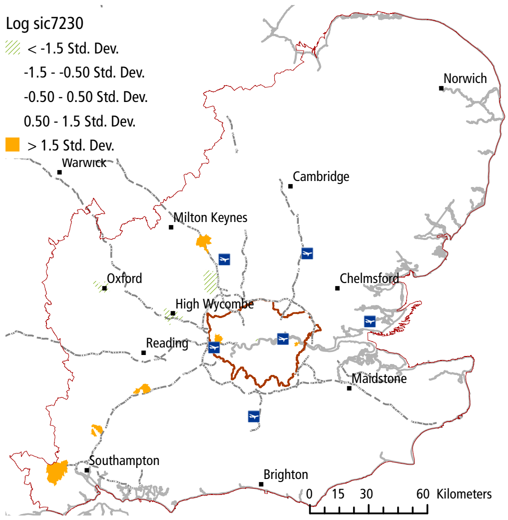


(f) Other Software Consultancy (Lognormal)

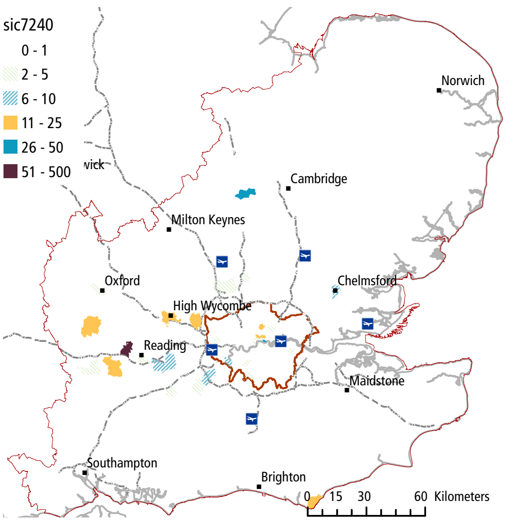
Figure 10.42: GSE Analytical Group LQs (Part 1)



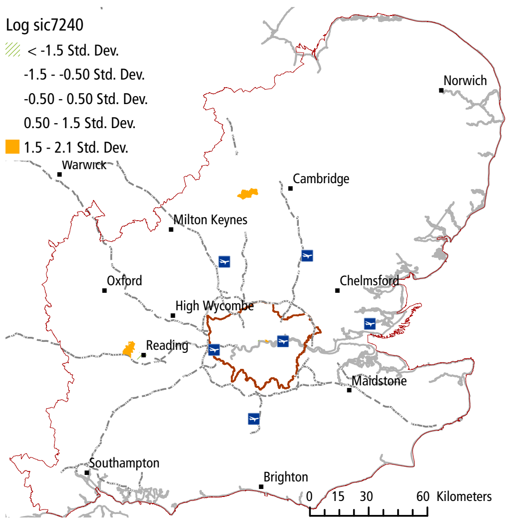
(a) Data Processing



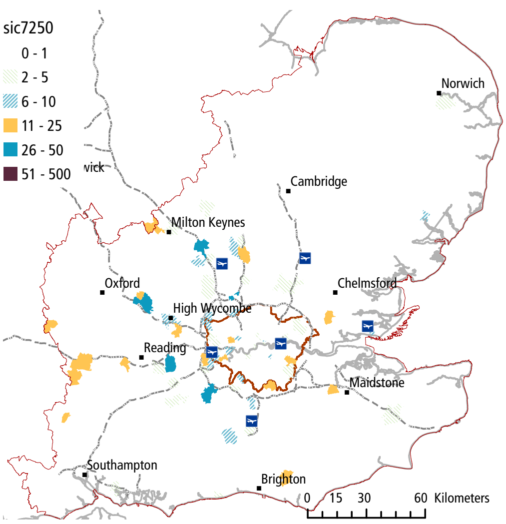
(b) Data Processing (Lognormal)



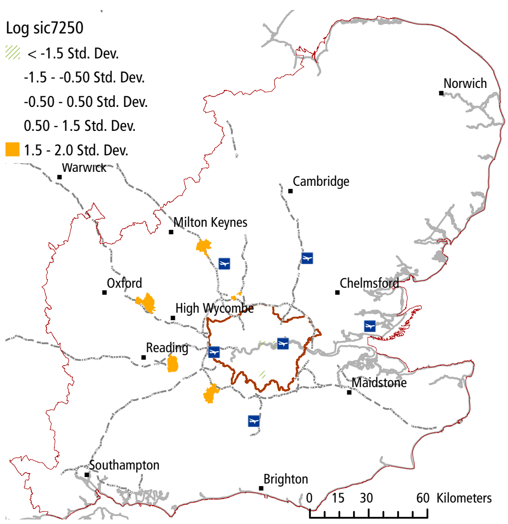
(c) Data Base Activities



(d) Data Base Activities (Lognormal)

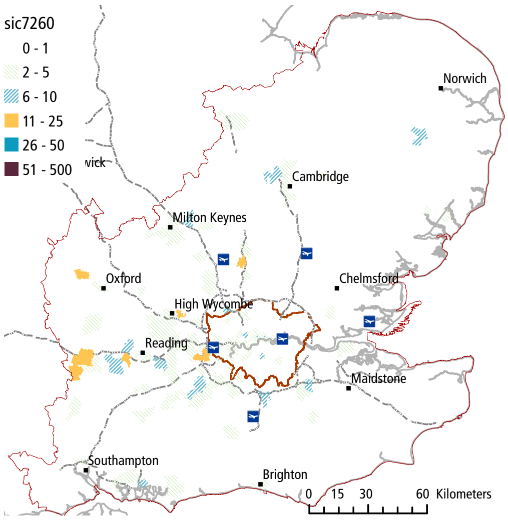


(e) Maintenance of Office/Comp. Equiment

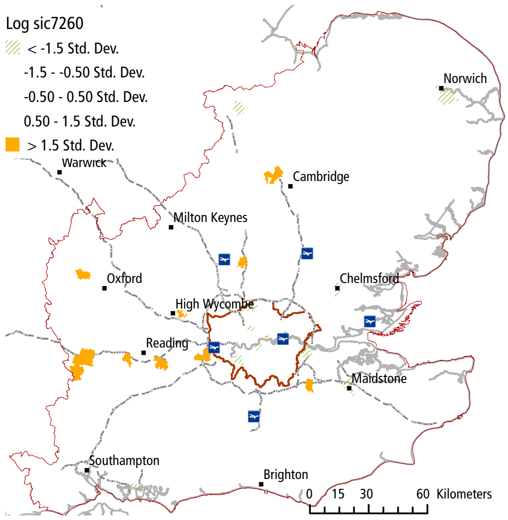


(f) Maintenance of Office/Comp.Equipment (Lognormal)

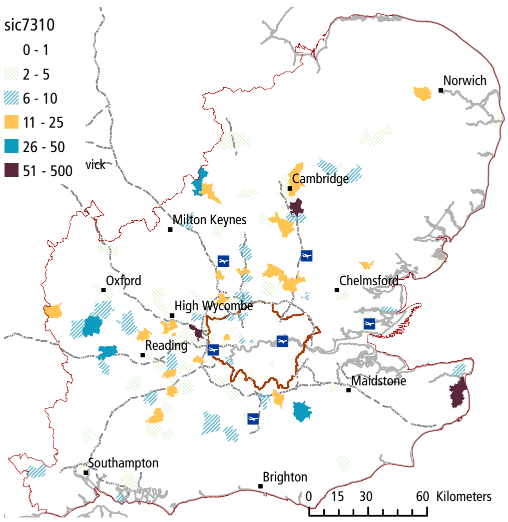
Figure 10.43: GSE Analytical Group LQs (Part 2)



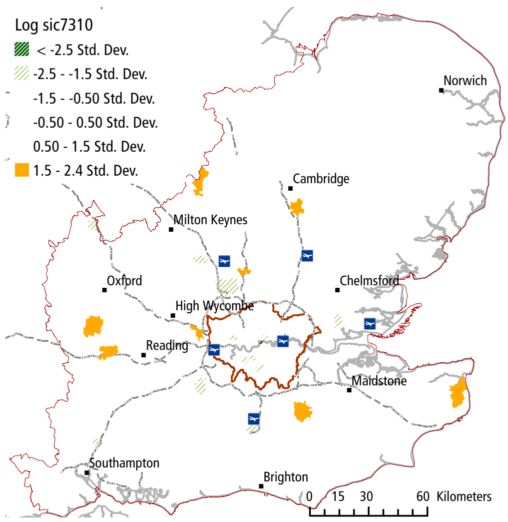
(a) Other Computer Activities



(b) Other Computer Activities (Lognormal)

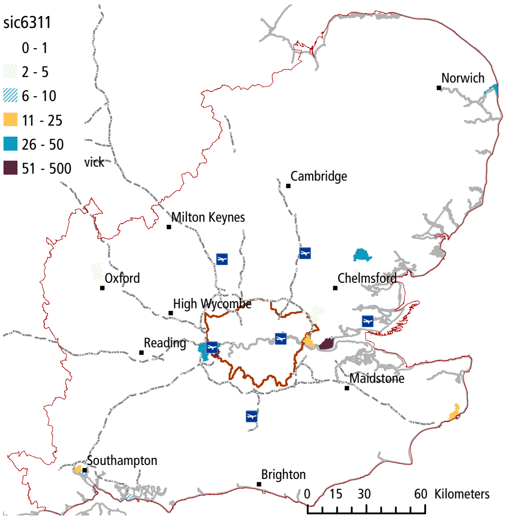


(c) R&D in Natural Sciences

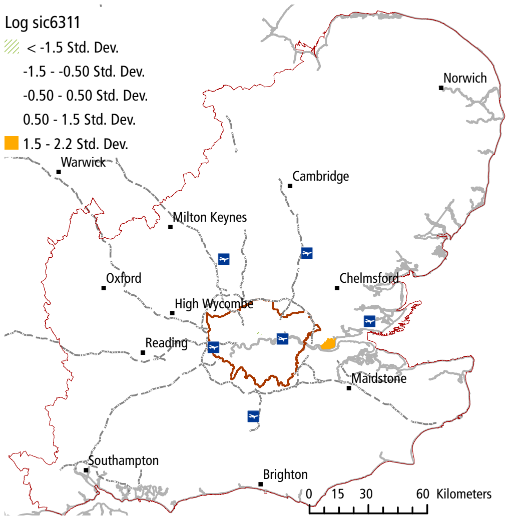


(d) R&D in Natural Sciences (Lognormal)

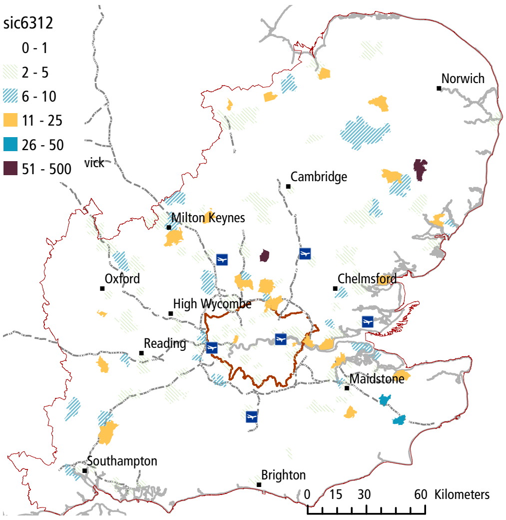
Figure 10.44: GSE Analytical Group LQs (Part 3)



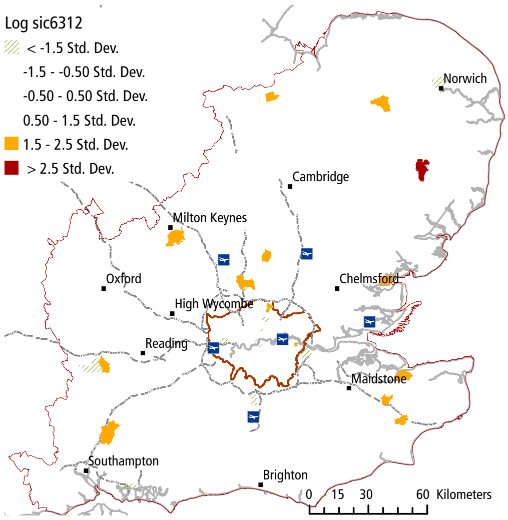
(a) Cargo Handling



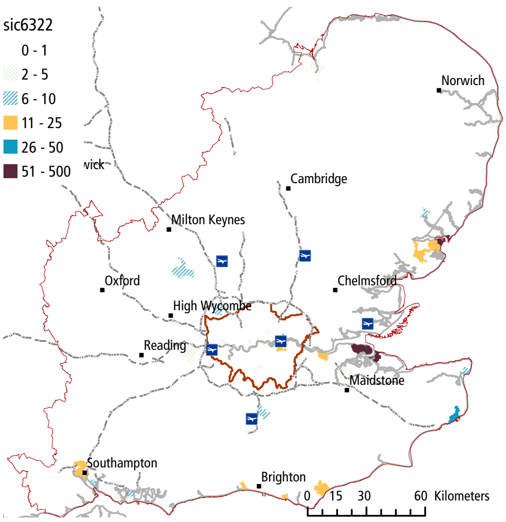
(b) Cargo Handling (Lognormal)



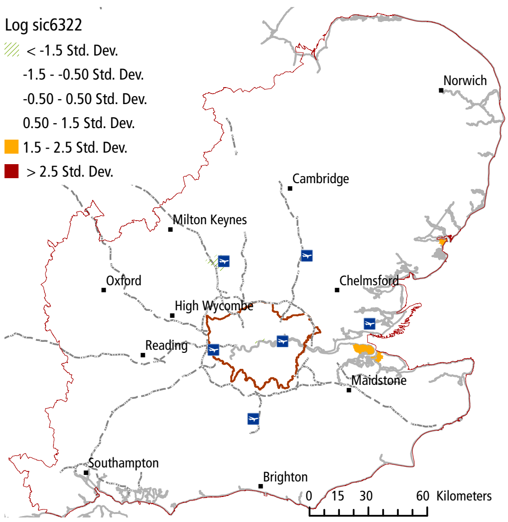
(c) Storage & Warehousing



(d) Storage & Warehousing (Lognormal)

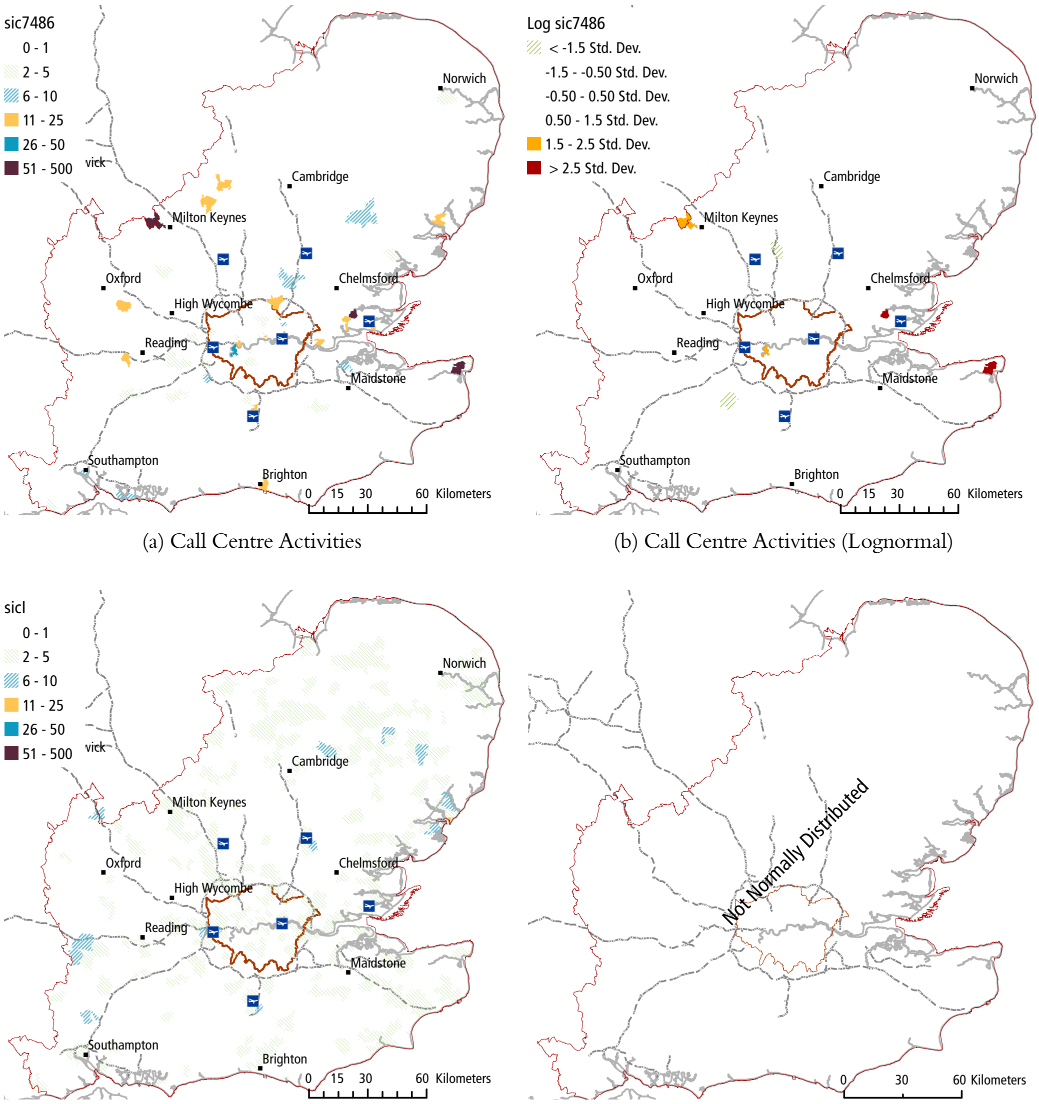


(e) Other Support Water Transport



(f) Other Support Water Transport (Lognormal)

Figure 10.45: GSE Flows Group LQs (Part 1)



(a) Call Centre Activities

(b) Call Centre Activities (Lognormal)

(c) sic I

(d) sic I (Lognormal)

Figure 10.46: gse Flows Group lqs (Part 2)

10.2 *Telecommunication Quotients*

The results in this appendix suggest that the TQ also has clear analytical value was for non-business activity, and that it might be a particularly useful tool for population and migration research. This is especially clear amongst the results for groups where migration is principally a means of accessing opportunity and where there is little overlap with business calling to major trading partners. Figures 10.51, 10.54, 10.53, 10.56, and 10.57a all demonstrate remarkable consistency between the known census demographics and the derived TQ for those countries. It would be interesting to see how this metric might work at the national scale in America, with its especially large numbers of migrants.

New York City

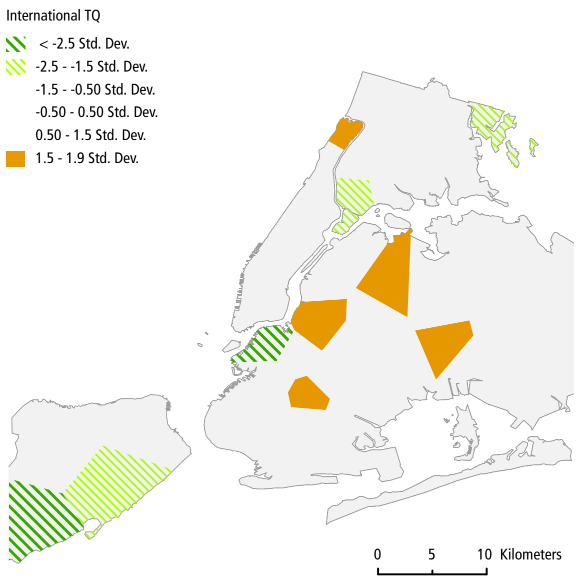
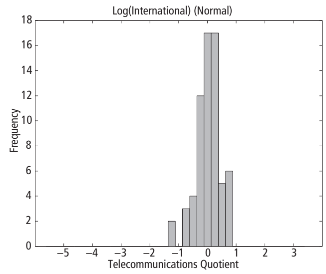


Figure 10.47: New York City STQs International

Figure 10.48: STQs International Distribution



The complex nature of international calling means that the results need to be considered a bit differently from the industrial distributions calculated using the same basic method. For instance, one of the first conceptual challenges that we encounter in Figure 10.47 is that the highest TQs are in residential areas. What makes this result more puzzling is that I had deliberately selected *only* international calling between the hours of 9 a.m. and 6 p.m. in the expectation that this would highlight business-related links: instead, comparison with Figure 10.1 (see page 360) shows that *none* of these locations have high ratios of employees to residents, and some do not even have large numbers of employees at all (see Figure 10.3a on page 362).

Assuming that the nature of the CLLI mapping process is not flawed (see the section Data Provision on page 226 for a fuller discussion), then the neighbourhoods of New York with the highest proportions of international calling are: Williamsburg, Woodside, Prospect Park South, Jamaica, and—the only CLLI in Manhattan—Inwood Hill/Fort George. Comparatively wealthy areas such as Brooklyn Heights, Staten

Island, and Pelham Bay seemingly use significantly *less* international telecoms, and all five of the 'most internationalised' areas are drawn from the lower two quantiles of income distribution (see Figure 10.3b on page 362). Furthermore, comparison with the percentage of Hispanic, Asian or White households (see Figure 10.4 on page 362) also reveals no particularly strong relationships between internationalisation and household composition.

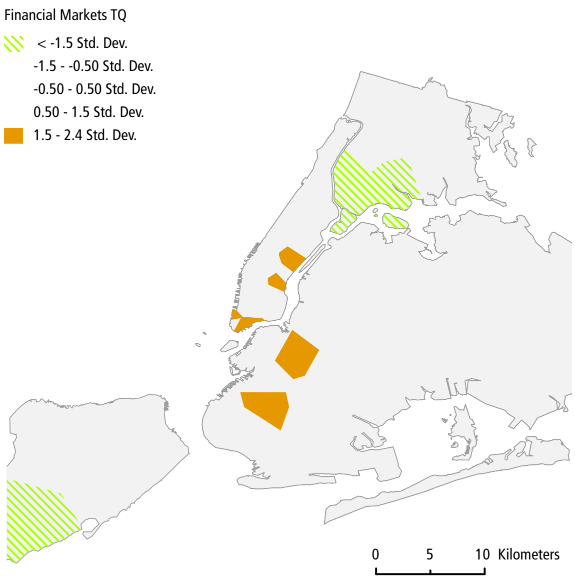
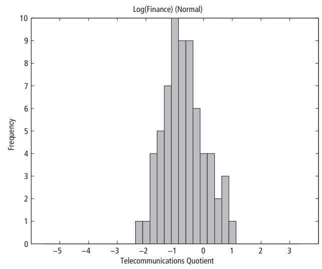


Figure 10.49: New York City STQs Britain & Japan

Figure 10.50: STQs Britain & Japan Distribution



However, we can unbundle these calls by country, and one of the most common assertions made about financially-oriented industries such as banks, consultancies, and hedge funds is that they have strong connections with the other two 'major world cities': London and Tokyo. So a TQ map of minutes to and from these two countries should enable us to pick out the centres of financial activity in the five boroughs. Figure 10.49 emphasises Wall Street and Mid-Town, as well as the Borough Hall area of Brooklyn, all of which are known centres of financial services (see Figures 10.2 on page 361, and 10.5 on page 363). Calling to and from Britain appears to be the principal driver of the significant linkage South of Borough Hall—this is the Midwood area of Brooklyn, known mostly for a TV/film production complex similar to White City in West London (see Figures 10.12a and 10.12e on page 373); without being able to examine call flow in greater detail, the fact that Outer London is the dominant destination of calls—by a massive margin—from this area certainly reinforces a tentative international 'creative complex' association.

For comparative purposes, a very different communications geography is suggested by Figure 10.51, in which calling activity to the Dominican Republic is highly concentrated at the North end of Manhattan: the Washington Heights neighbourhood is the original home of Dominican migrants to New York City (where they make up some 42% of Latinos), but the telecommunications data also picks up a more recent movement—largely the result of gentrification in Upper Manhattan—out of Manhattan and across the river to the Bronx neighbourhoods of Morris Heights and University Heights (Limonic, 2008). Again, it is worth considering the fact that this is data drawn from the period between 9 a.m. and 6 p.m. when we would expect a great deal of calling to be business-related. Unfortunately, the data is not available to enable me to determine whether these are Dominican-run businesses or simply very significant levels of household calling.

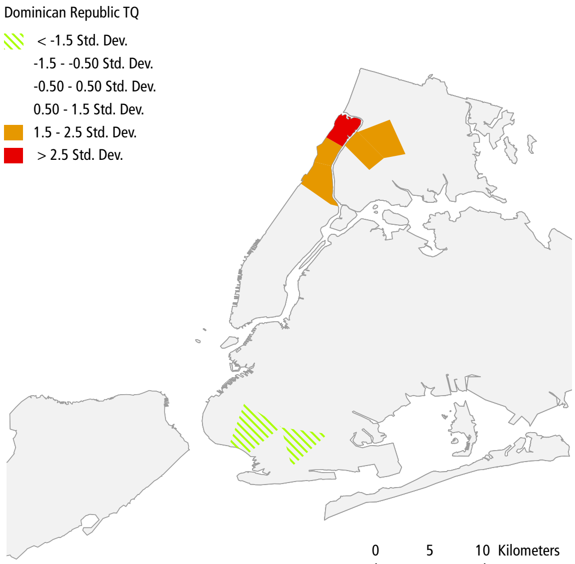


Figure 10.51: New York City STQs the Dominican Republic

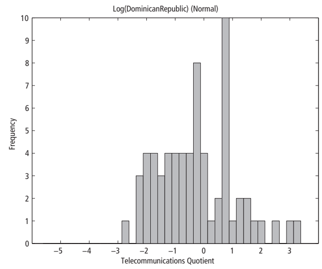
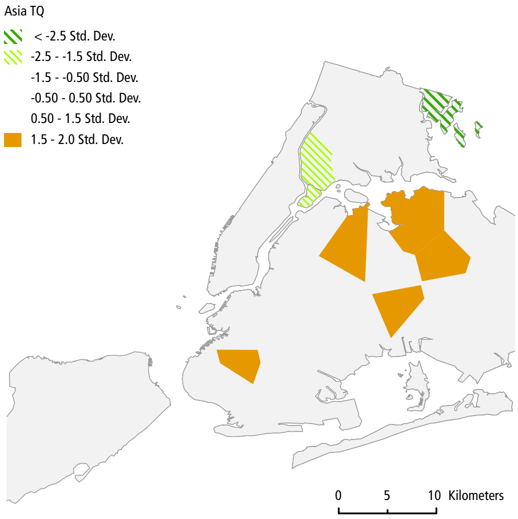
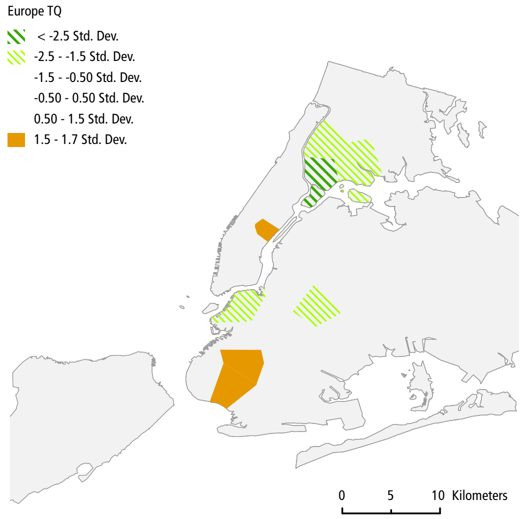


Figure 10.52: STQs Dominican Republic Distribution

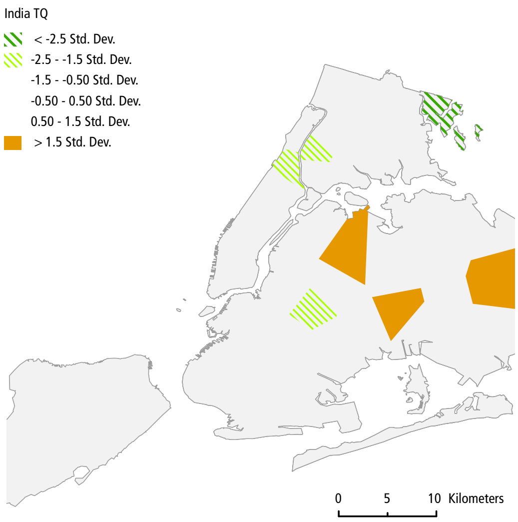
In the case of New York City it is possible that the sample size played a role—New York is already a very international city, so to use it as the basis for comparison (as a region R, if you will) seems problematic even though this same approach was employed successfully with the LQ.



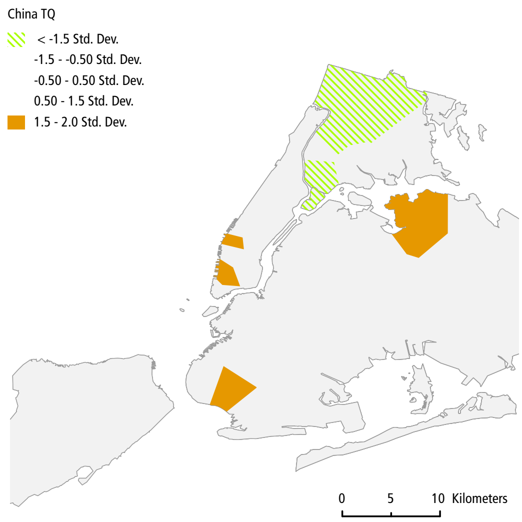
(a) Asia



(b) Europe



(c) India



(d) China

Figure 10.53: NYC STQs

London

In the case of New York City, it was helpful to look at the distribution of calls to and from Latino countries since migrants from Central America make up a significant proportion of the total population. In much the same way, over the years large numbers of people have arrived in London from the Indian subcontinent and Figure 10.55 gives us a sense of how 'Hindus'—whose location was determined using surname maps by the London Profiler project[3]—are distributed around London. Figure 10.54 shows the intensity of calling to and from India, and although the numbers will not line up exactly since Muslim Indians make up a significant minority of migrants, the fidelity of the TQ map to the name-distribution map is quite remarkable and picks up Southall, Barking, Croydon, and Harrow, amongst others. Note too, that although Barking did not feature for overall international calling, it does so very prominently here.

[3] See: http://www.londonprofiler.org.uk

Figure 10.54: London TQs India

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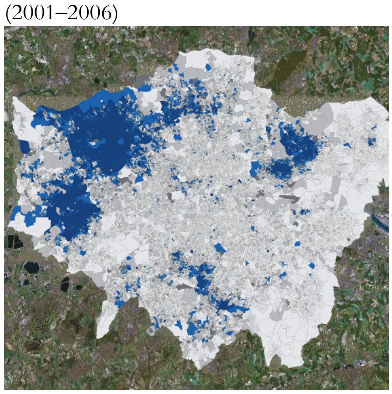
Figure 10.55: Concentration of Hindi Surnames in London (2001–2006)



Similar maps for Turkey (see Figure 10.57a on page 416) and Poland (see Figure 10.57b on page 416) suggest that minority groups with strong social and economic links to a 'home' country are particularly amenable to mapping with a TQ approach. In that sense, these findings fit well with observations by Barnett and Choi (1995, p.262) that countries that share a common language and are in close proximity tend to communicate more, but we can now extend this finding down to the micro-scale and connect it to population migrations. In turn, this means that we have strong, if indirect, support for some of the core elements of the 'global cities' hypothesis advanced by authors such as Sassen (1991, 2008) and now being pursued by the Globalisation and World Cities Group (cf. Smith and Timberlake, 2002; Taylor et al., 2002). There is, in other words, a 'geography of talk' that takes in both 'elite' and 'opportunity' migration, and could be used as an investigative tool.

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(a) Asia

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(b) Europe

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(c) U.S.

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(d) South America

Figure 10.56: London TQs

Figure 10.57: Comparison of London TQs and Surnames

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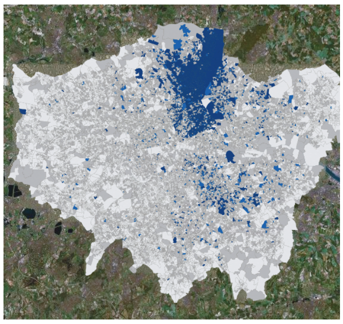
(a) Turkey TQs



(b) Concentration of Turkish Surnames in London (2001–2006)

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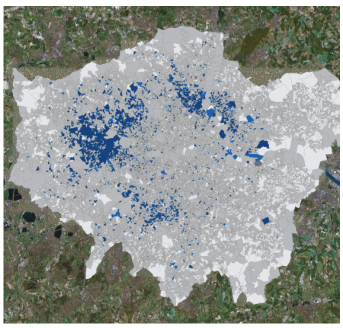
(c) Poland TQs



(d) Concentration of Polish Surnames in London (2001–2006)

Greater South East of England

Finally, for a completely different geography of telecoms activity, we can turn to Figure 10.58, which maps the intensity of calling to and from Turkey. It is quite interesting to juxtapose this map with Figure 10.60 (page 418), which plots the distribution of calling to and from India. The latter is strongly Western-oriented, taking in well-known enclaves such as Southall, but also showing a clear bias towards centres such as Reading, High Wycombe, Oxford, and Milton Keynes. In contrast, although the scale should be taken into account, calls with Turkey have a stronger eastward element, with a particularly large grouping running North and East of Islington, through Hackney and Haringey, but also seeming to congregate near to Luton and Stansted airports. Asian migrants to England, particularly following their expulsion from Kenya and Uganda, tended to settle near to their point of arrival at Heathrow Airport (BBC Four, 2009a,b), and I wonder if a similar process might now be operating for other, more recent immigrant groups?

Figure 10.58: GSE TQs Turkey

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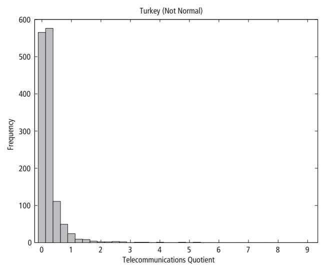
Figure 10.59: TQs Turkey Distribution



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(a) Asia

Suppressed from electronic copy at request of research partner

(b) Europe

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(c) India

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(d) South America

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(e) China

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(f) U.S.

Figure 10.60: GSE TQs for Other Countries and Regions

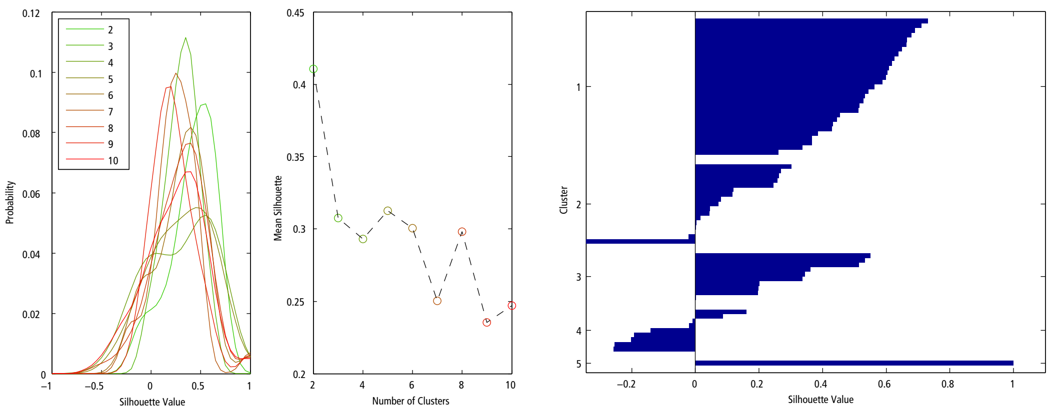
11

Appendix C: Eigenplace Analysis

11.1 New York City

The fact that there are just 66 CLLIs in New York makes it faster and easier to compute the eigenvalues and Fourier frequencies used in the classification process; however, I was concerned that the larger 'cell' sizes of North American CLLIs would make it more difficult to localise activity and to assign it to a singular use or set of uses. This is a very real risk since some of the CLLIs serve areas containing more than 100,000 workers during peak daytime hours!

Although I had originally intended to use dedicated (PBX) and land-line calls as the basis for the analysis, it soon transpired that the very distinct pattern of PBX usage inevitably skewed the clustering results in much the same way that I had suggested an analysis of calls to and from the Turks and Caicos Islands might: many CLLIs had no usage at all, while a few had truly massive levels of inbound and outbound calling. The result was that CLLIs with dedicated lines tended to end up in their own cluster, and so I turned to landline and mobile data as the basis for the New York analysis. The fact that we have information about calling from mobile phones might also enable us to find systematic differences in the way that different populations use telecoms to remain in touch with distant colleagues, collaborators, friends, and family.

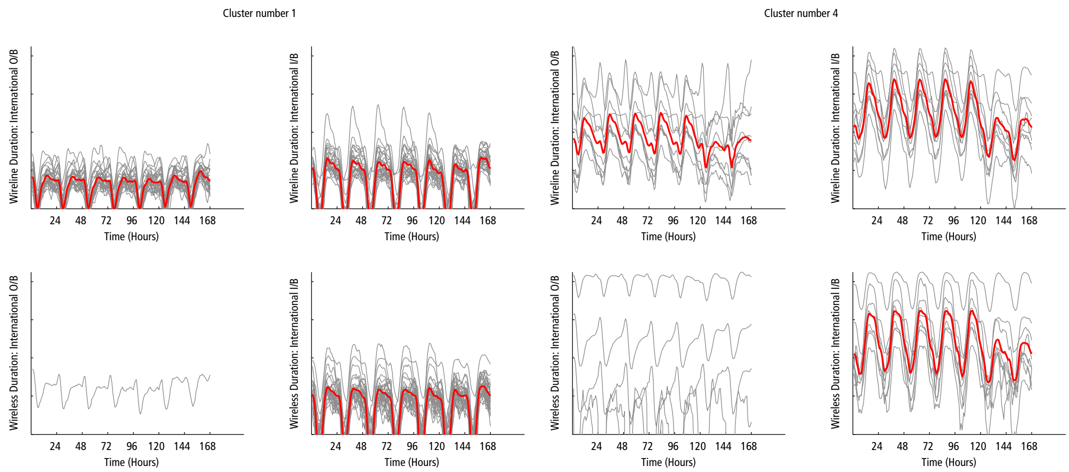


(a) Cluster Fitness (b) Clustering Results

Figure 11.1: Cluster Number Selection

Further experimentation also demonstrated that another early idea that I had had—to use domestic calling as a baseline data set against which to control for large variations in country- or region-specific calling[1]—also tended to founder on the fact that important differences in the much larger domestic data volumes tended to overwhelm more modest differences in calling to and from a particular country or state. In short, in New York City domestic differences dominated the feature-selection process in much the same way that domestic flows could swamp the results of the TQ analysis.

[1] For instance, to feed into the eigenplace process inbound and outbound calling data for both wireless and wireline calls to France *and* all domestic calls



(a) Cluster 1 (b) Cluster #4

Figure 11.2: Representative Signals

In this example, even before projecting these clusters on to a map, we can infer that Figure 11.2a is taken from predominantly residential areas, while Figure 11.2b is drawn from business areas. We can predict this because Cluster 1 shows little weekday/weekend variation (there is, in fact, even a small up-tick on Sunday evenings), while Cluster #4 shows an enormous fall-off in usage over the weekend *even though* usage levels are still generally higher than they are in Cluster 1 at the same time of day. The ability to measure and use variations across the entire week as the basis for clustering is what makes the eigendecomposition and Fourier Transform approach more powerful than a Telecommunications Quotient—if we were to take a purely static approach then this cyclical aspect would be entirely lost. Representative signals for the other three clusters can be found in Appendix C: Eigenplace Analysis on page 422.

We can now turn to Figure 11.3 to see how well the eigenplace approach to urban analysis matches up with an understanding of the city derived from more traditional sources. At the risk of overemphasising the distinctions between the clusters, I have here (as elsewhere in this section) coloured Cluster #4 in dark red because of its significance, in this case it is to highlight the cluster's concentration in Lower Manhattan and Mid-Town. Comparison to Figures 10.2b and 10.5 (see pages 361 and 363 respectively) suggests that the clustering process is, in part, selecting for the volumes associated with financial services and subsidiary activities in Lower and Mid-Town Manhattan. It is undoubtedly also connected to calling from high-income residential areas (see Figure 10.3b), which are more likely to place and receive direct-dial international calls from landlines than are lower-income areas. Meanwhile, the distinct usage pattern at JFK Airport (especially as captured in this data) results in the clustering process assigning it to its own group (Cluster #5).

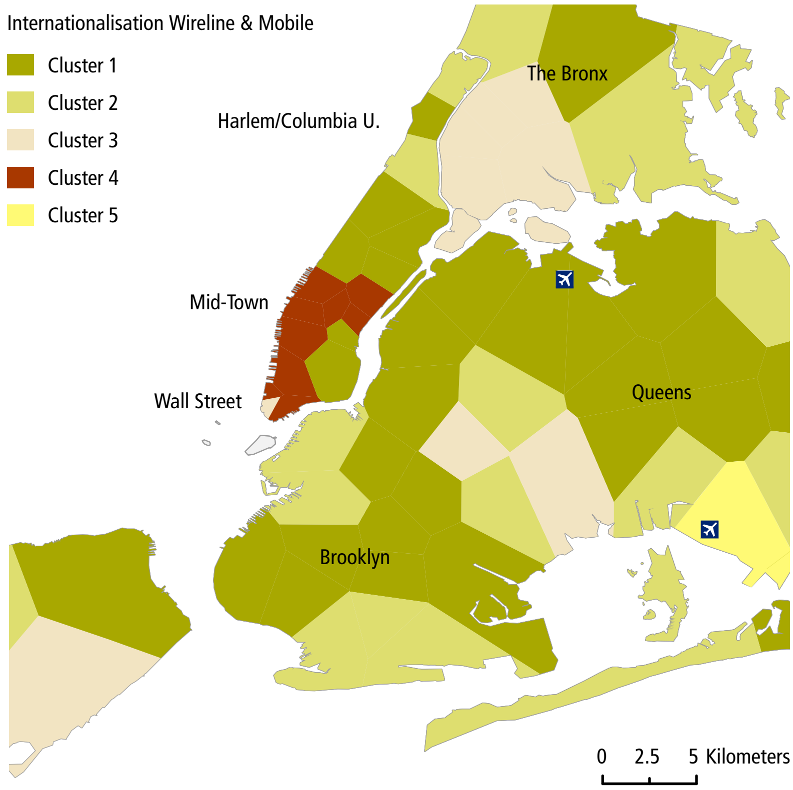
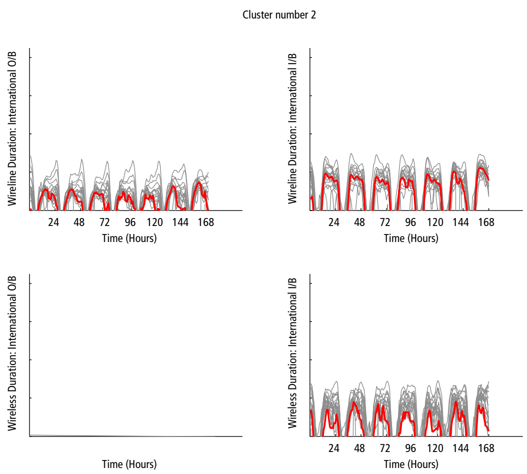


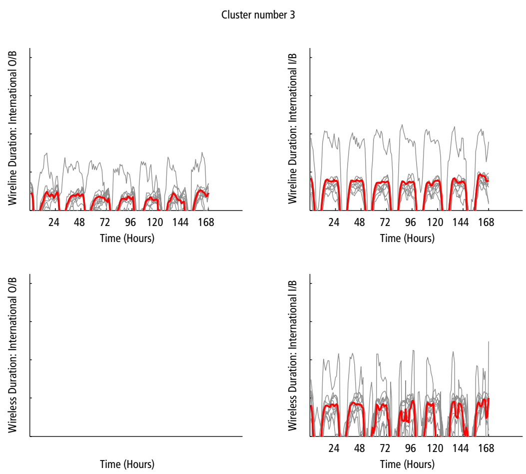
Figure 11.3: International Eigenplaces in New York

In contrast to those two groups, Clusters 1, 2, and 3 are initially more difficult to interpret from the mix of spatial and temporal information available to us. It seems fairly clear that the distribution is not random, but teasing out the differences requires more careful scrutiny: Clusters 1, 2 and 3 differ in *part* in magnitude, but the more fundamental difference is actually the pattern of calling later in the evening. And whereas Clusters 2 and #4 generally show constant (or even increasing) use until quite late, Cluster 1 shows a steady decrease over the course of the day. Since this pattern recurs across both mobile and fixed line usage as well as, to a lesser extent, inbound and outbound calling, what the eigenplace analysis process seems to have identified is the timezone of the parties on the other end of the call.

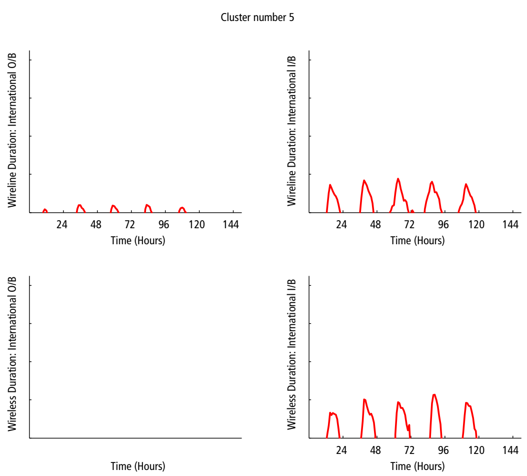
We will investigate this aspect of the New York City data in more detail in the subsequent figures, but if we lump Clusters 2 and #4 together then we have—very generally speaking—identified areas associated with domestic migrants, as well as those from Central and South America. And while Cluster 1 contains a mix of income groups (see Figure 10.3b), the areas in the cluster are all associated more strongly with households originating in, or with connections to, Europe, Asia, and Africa. Significantly, the analysis has even picked out the Lower East Side/Chinatown and Little Italy as being distinct from the surrounding areas of Lower Manhattan, which tend to be more affluent and contain fewer recent migrants.



(a) Cluster 2



(b) Cluster 3



(c) Cluster 5

Figure 11.4: Internationalisation Clustering

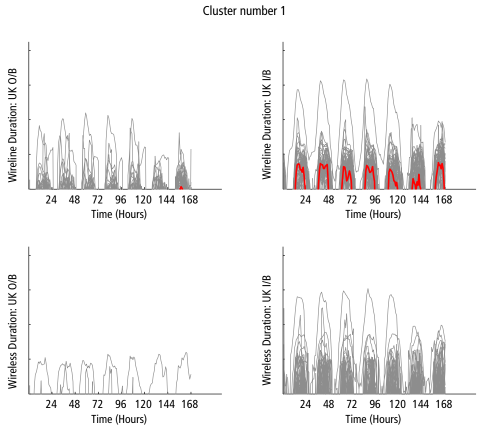
These are very broad conclusions, and the relatively small number of CLLIs (though this obviously draws on an enormous underlying data set), together with the very large number of households and businesses in each CLLI, makes it difficult to definitively link each cluster to just one type of activity. The issue of the interaction between the scale of the 'analytical unit' and the density of the built environment is one that had previously been identified in studies of mobile calling in Rome (Reades et al., 2007, 2009), but it is nonetheless reassuring to find that the New York data at least yields reasonable results in spite of its vastly different social and economic composition.

National Geographies

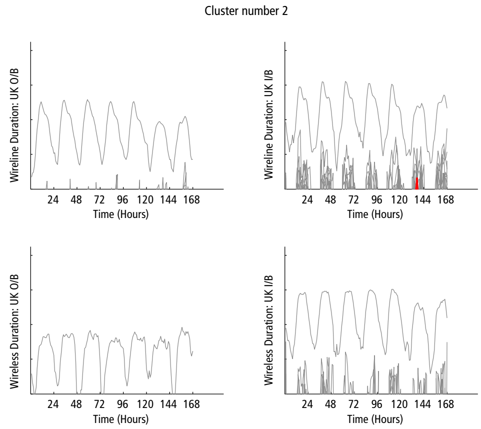
With only one example it is, of course, entirely possible that the differences identified by the clustering process are not particularly important, or that the features selected would lead to the same results being obtained for every data set. In order to test this assumption—something that has not previously been possible with aggregate data from WiFi hotspots (Calabrese et al., 2010) or Roman cell towers (Reades et al., 2009)—I turned to data on calls to Britain, India, China, and the Dominican Republic on the basis that these should generate markedly different clustering patterns. For the sake of brevity, only the maps are produced here in Figure 11.6, and the representative signals, silhouettes, and *k*-means distribution are all available in Appendix C: Eigenplace Analysis on pages 424 to 428.

The eigenplace analysis yields four substantially different geographies that accord remarkably well with personal and statistical knowledge of the city (see page 429 for country of birth by Zip Code maps using 2000 Census data). Figure 11.6a does, however, highlight one of the challenges of analysis at this resolution: the mixing of different activities—residential and business especially—within a single cluster. For instance, the members of Cluster 3 in Lower Manhattan are much more likely to be related to business calling than they are to residential, and Figures 10.1 (see page 360) and 10.3a (see page 362) show just how much employment is concentrated in these two areas. However, further North in Mid-Town and on the Upper East and Upper West Sides, as well as across the East River in Brooklyn, the situation is very different: although some of these areas have low median incomes, they are also incorporate affluent residential parts of the city such as Park Slope (North and South) and trendy Williamsburg which are likely to use landlines for personal calling.

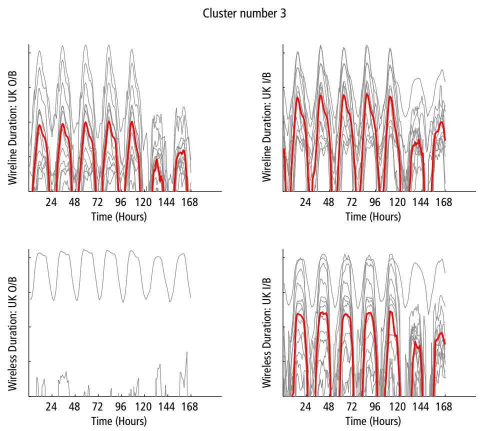
Figure 11.6b highlights the Lower East Side/Chinatown, as well as the CLLI covering Canal Street as it extends towards the Holland Tunnel; it also picks up well-known 'satellite' areas of Chinese migration in Sunset Park (Brooklyn) and Flushing (Queens), together with the emerging 'Chinatown' in Homecrest (on Avenue U in Brooklyn). Cluster 3 (Figure 11.6c) hewes closely to the highest residential densities of people of Indian origin; and Cluster 3 (Figure 11.6d) picks up many of the neighbourhoods with a strong Dominican presence. This last figure also makes clear the link between timezones and calling cycles discussed above: the up-tick in evening usage (because both countries are in the same timezone) highlights the residential dimension of Cluster 3 (see also Figure 11.9 on page 428) while Cluster 1 largely lacks this dynamic.



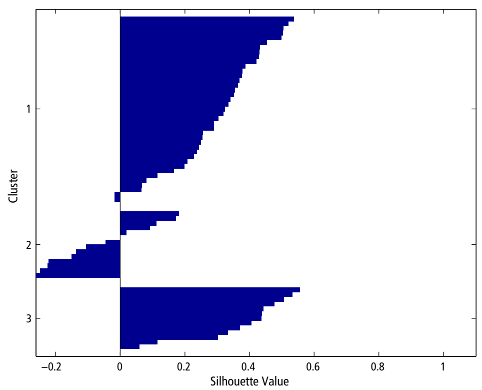
(a) Cluster 1



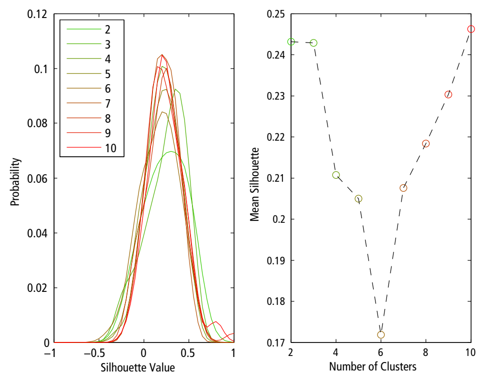
(b) Cluster 2



(c) Cluster 3

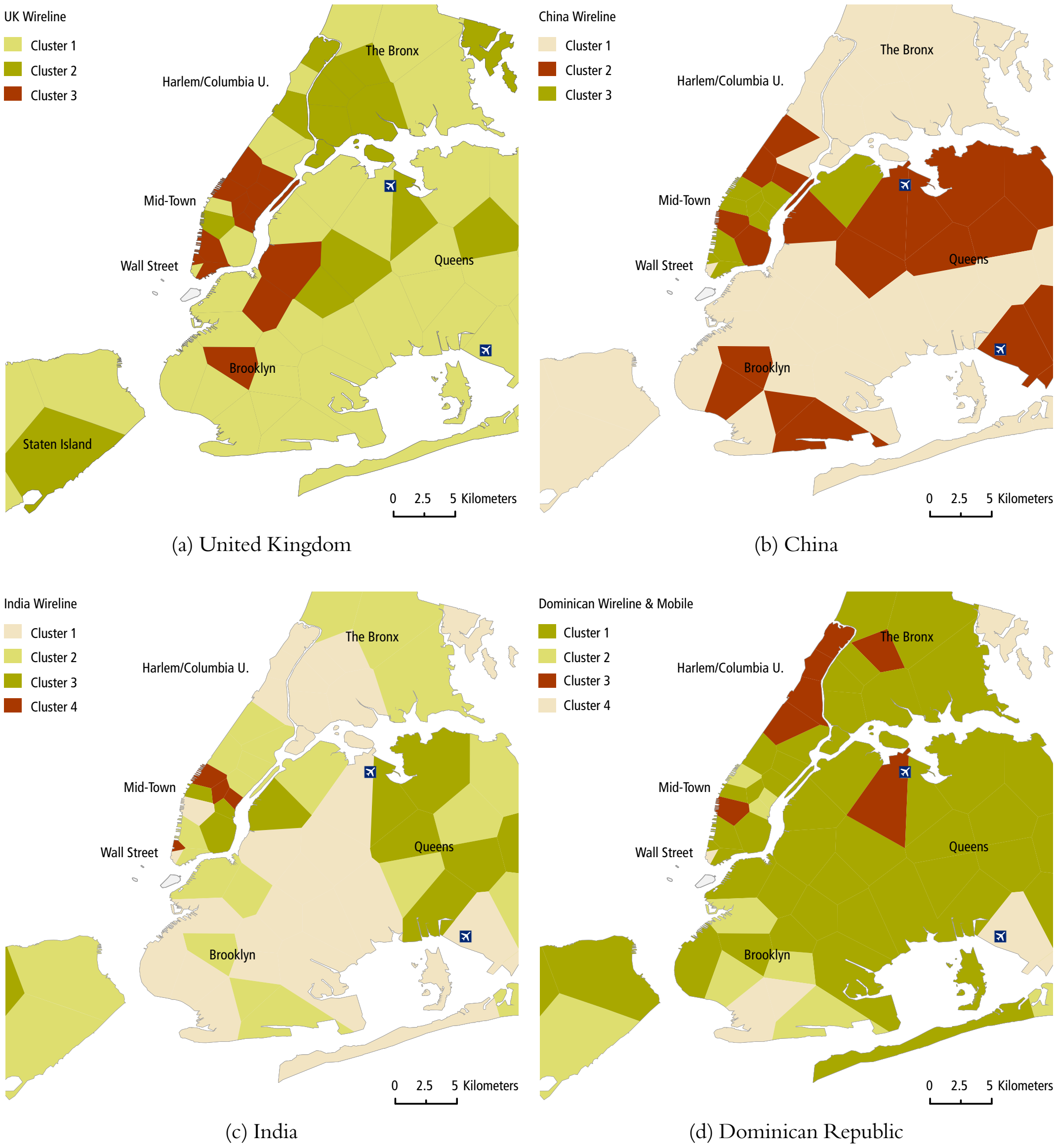


(d) Silhouette



(e) Cluster Selection

Figure 11.5: British Clustering



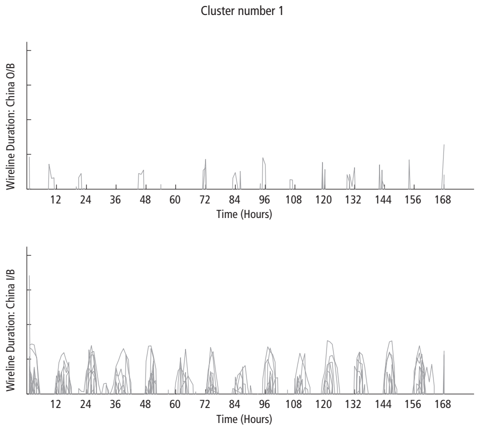
(a) United Kingdom

(b) China

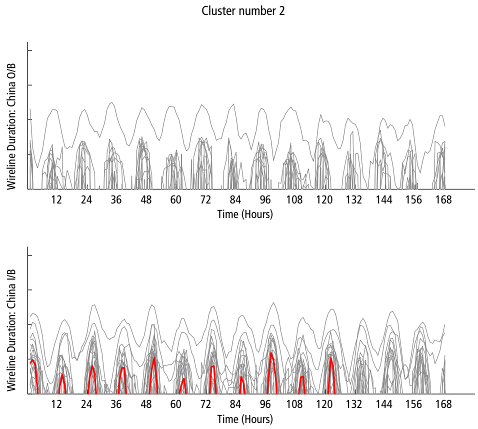
(c) India

(d) Dominican Republic

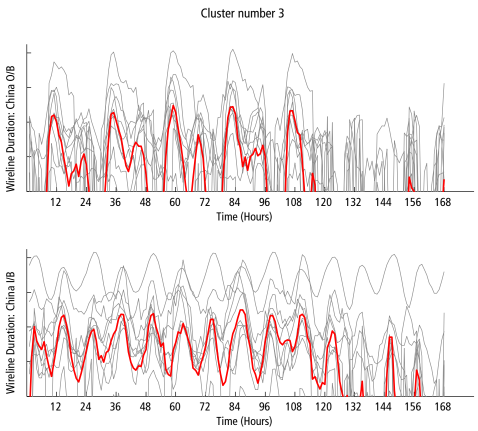
Figure 11.6: New York Eigenplaces



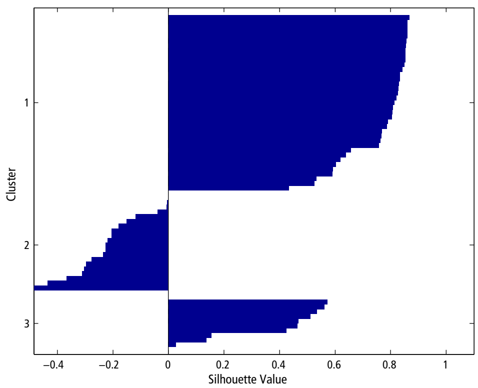
(a) Cluster 1



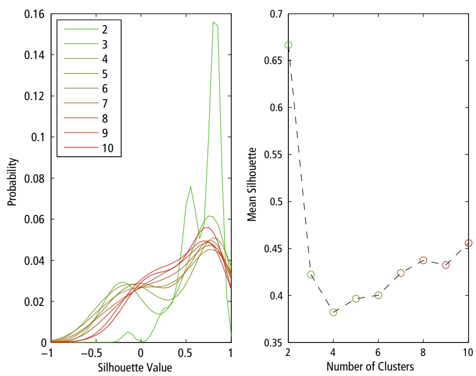
(b) Cluster 2



(c) Cluster 3



(d) Silhouette



(e) Cluster Selection

Figure 11.7: Chinese Clustering

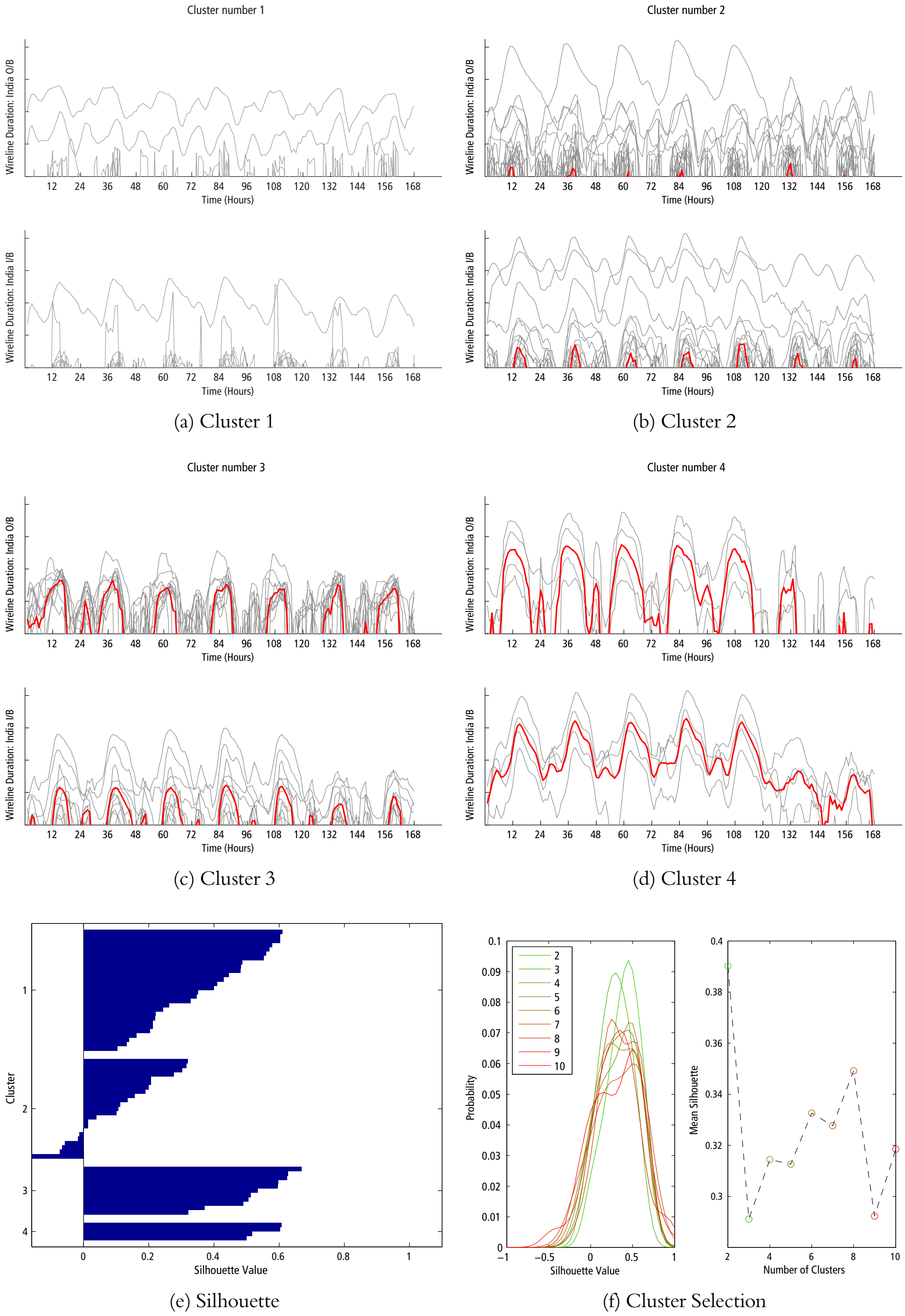
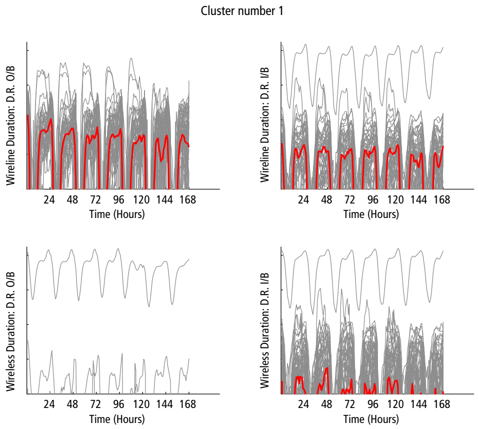
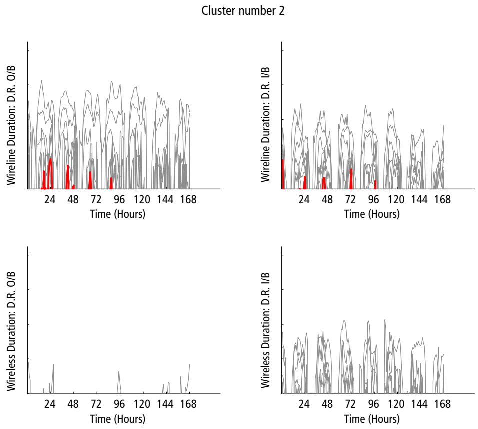


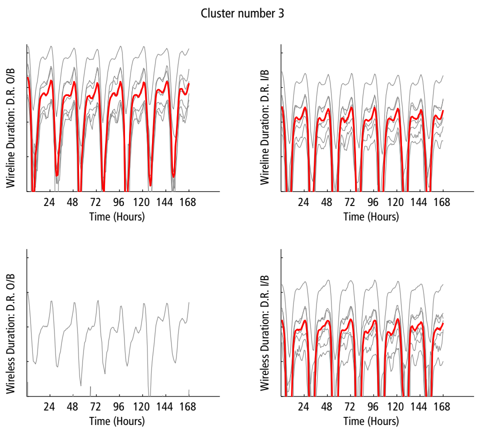
Figure 11.8: Indian Clustering



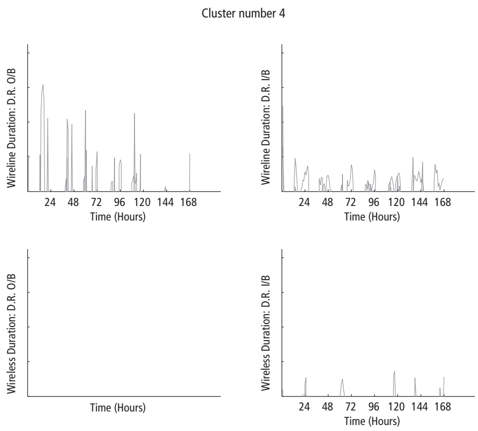
(a) Cluster 1



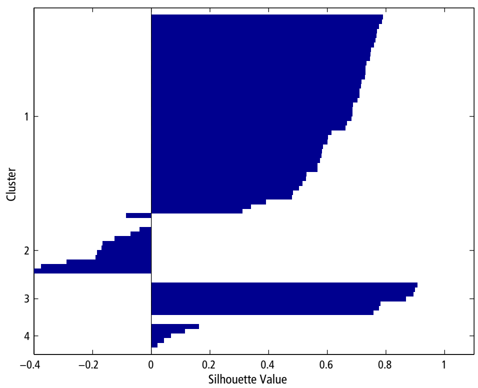
(b) Cluster 2



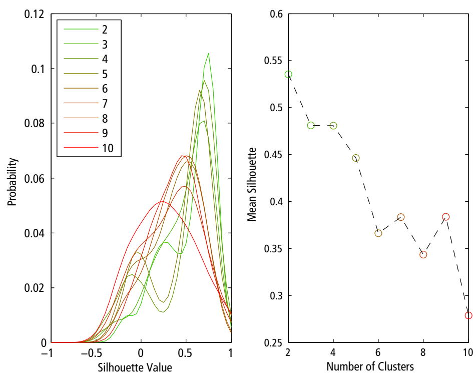
(c) Cluster 3



(d) Cluster 4

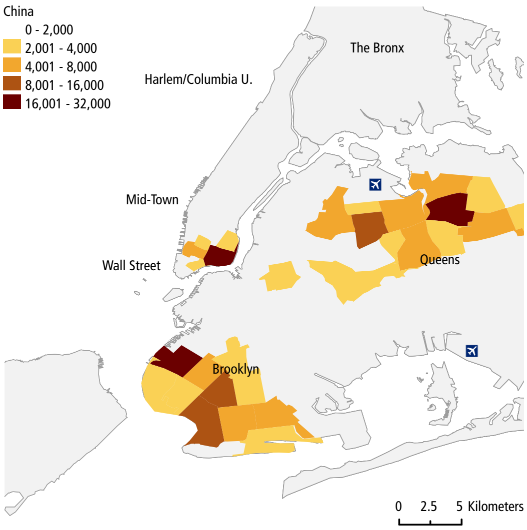


(e) Silhouette

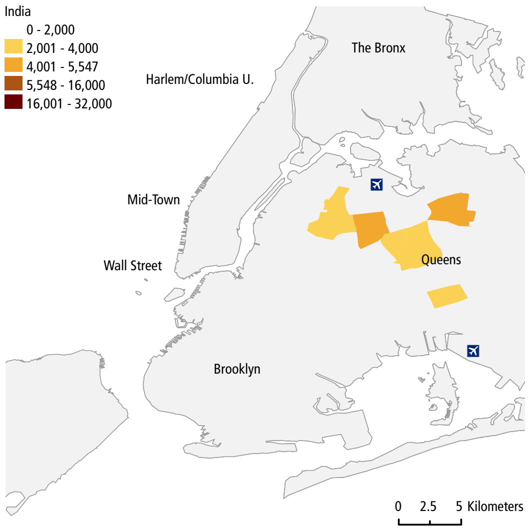


(f) Cluster Selection

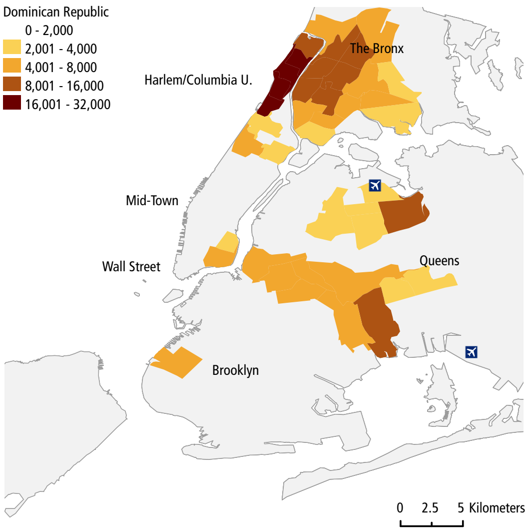
Figure 11.9: Dominican Clustering



(a) China



(b) India



(c) Dominican Republic

Figure 11.10: New York Populations by Country of Birth

11.2 London

Figure 11.11: India & Pakistan

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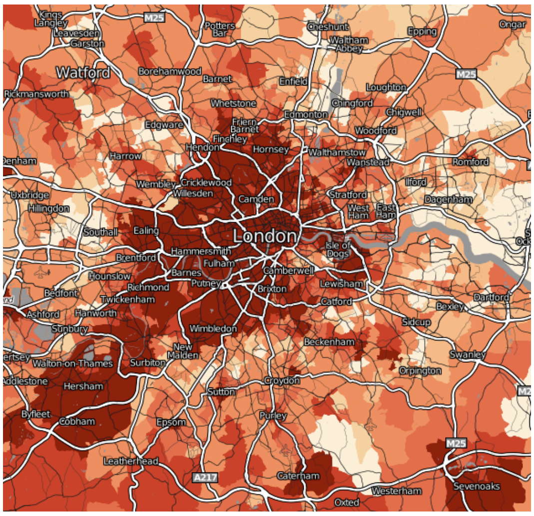
India & Pakistan

Shifting our focus to London, it is helpful to begin with equally social geographies since they will help us to quickly understand whether the higher spatial resolution of the U.K. data is a boon or a curse in terms of the analysis. One of the easiest maps to calculate, and one of the distributions with which many Londoners are intimately familiar, is the distribution of South Asian—by which I mean Indian and Pakistani—populations. The distribution of Hindi names previously shown in Figure 10.55 (on page 414) is clearly only a partial picture of the distribution of households, but there is a clear connection to the concentrations of calling captured in Figure 11.11. Examination of the representative signals (see Figure 11.17 on page 436) highlights the ways in which the behaviours differ for each exchange area group.

Other National Geographies

Taking two other migrant groups in London, we can see that the finer resolution of the British exchange is providing us with a more nuanced social geography with, again, entirely plausible results from the eigenplace clusters. Differences between the two geographies are perhaps overly emphasised by the use of a chloropleth map (*i.e.* colourised thematic map) since, in combination with the exclusive nature of the *k*-Means clustering, it causes areas to be assigned to one, and only one cluster. Nonetheless, the overall correspondence is clear.



(a) Australia (CensusProfiler.org)

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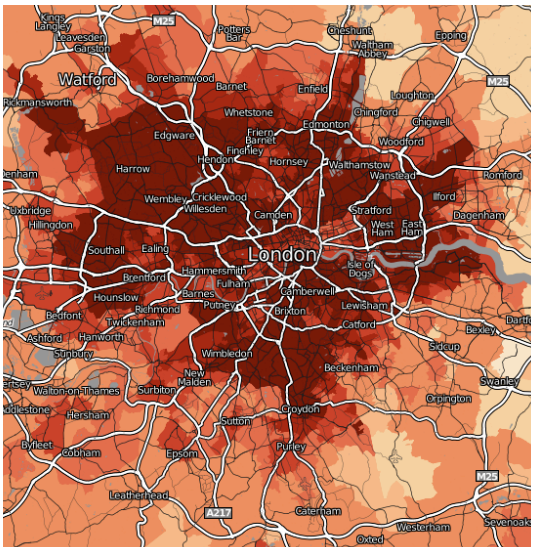
(b) Australia (Eigenplaces)



(c) Africa (CensusProfiler.org)

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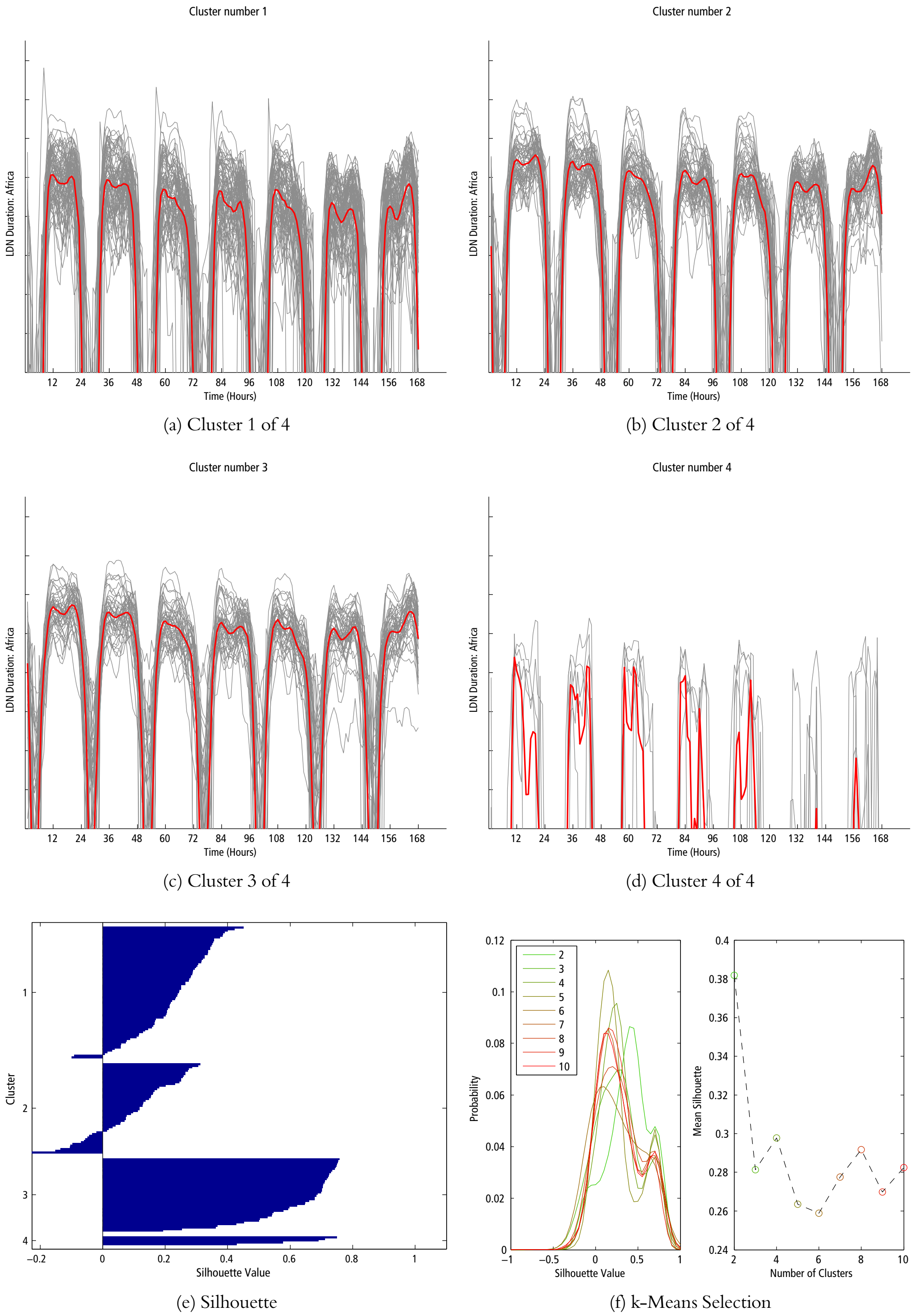
(d) Africa (Eigenplaces)

Figure 11.12: Other National Geographies



(a) Cluster 1 of 4

(b) Cluster 2 of 4

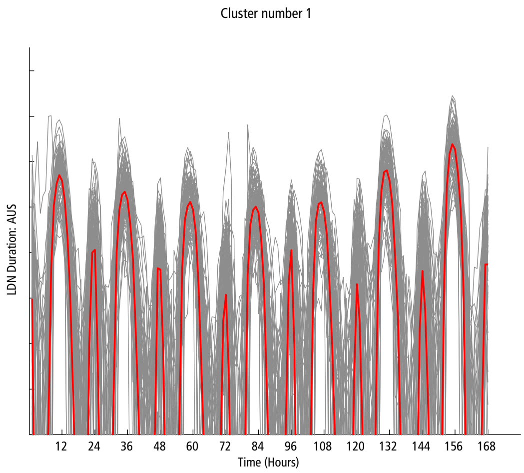
(c) Cluster 3 of 4

(d) Cluster 4 of 4

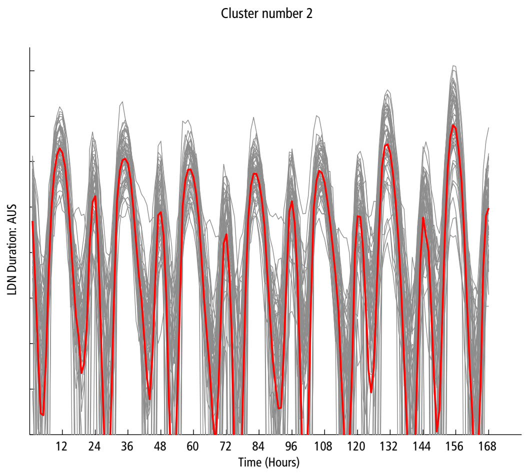
(e) Silhouette

(f) k-Means Selection

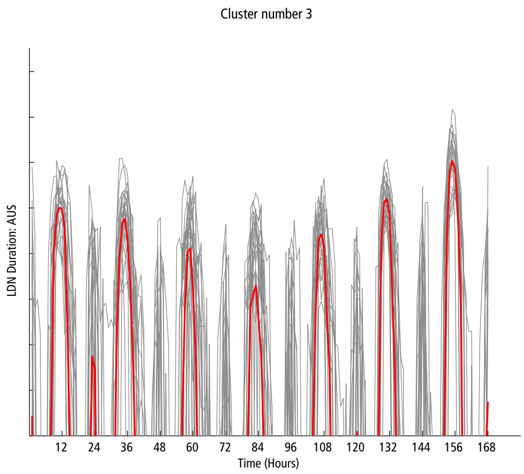
Figure 11.13: African Clustering



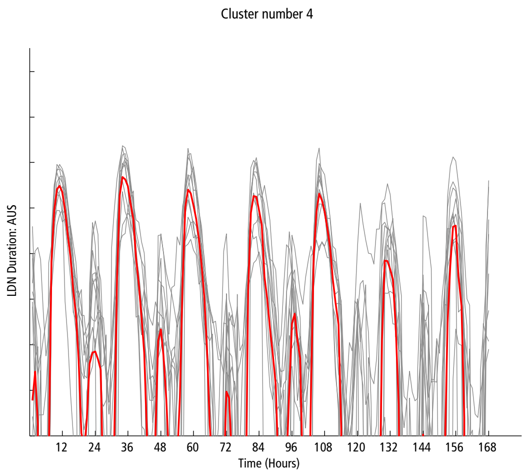
(a) Cluster 1 of 4



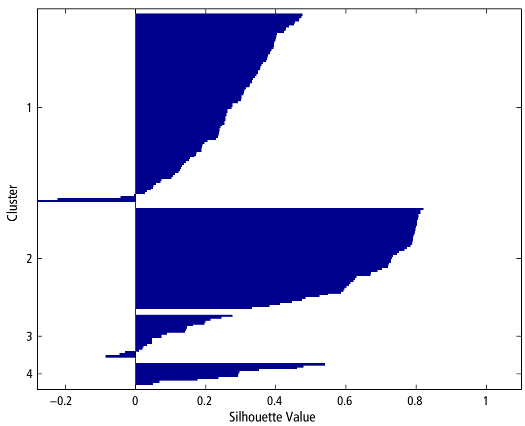
(b) Cluster 2 of 4



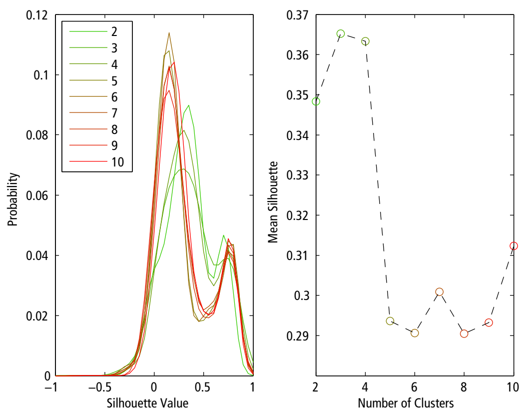
(c) Cluster 3 of 4



(d) Cluster 4 of 4



(e) Silhouette



(f) k-Means Selection

Figure 11.14: Australian Clustering

Figure 11.15: Brazilian Eigenplaces

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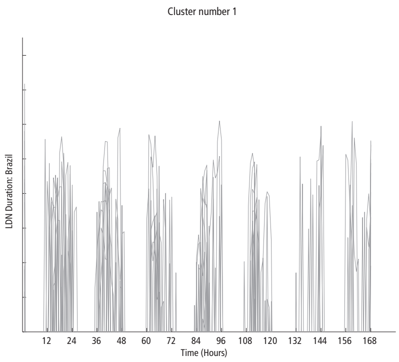
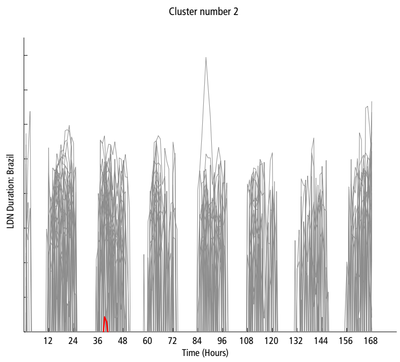
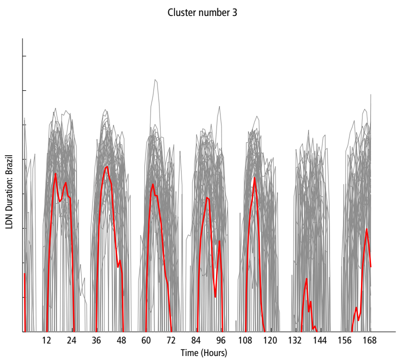
Figure 11.16: Brazilian Clustering



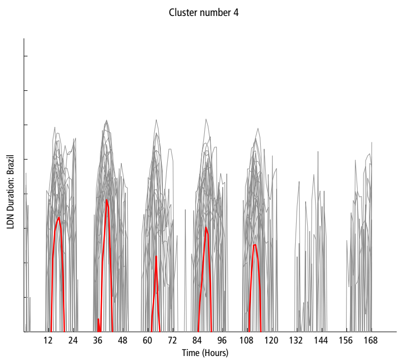
(a) Cluster 1 of 4



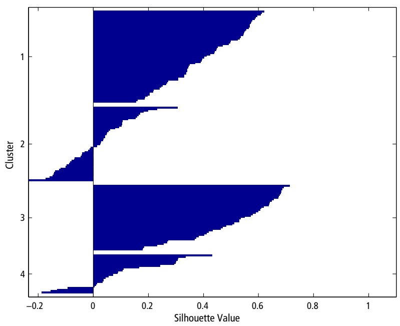
(b) Cluster 2 of 4



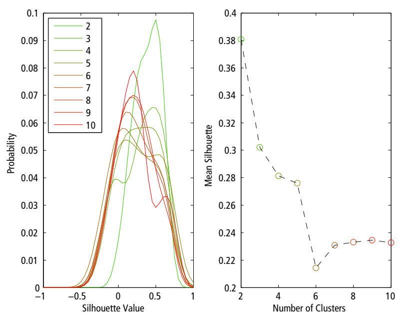
(c) Cluster 3 of 4



(d) Cluster 4 of 4

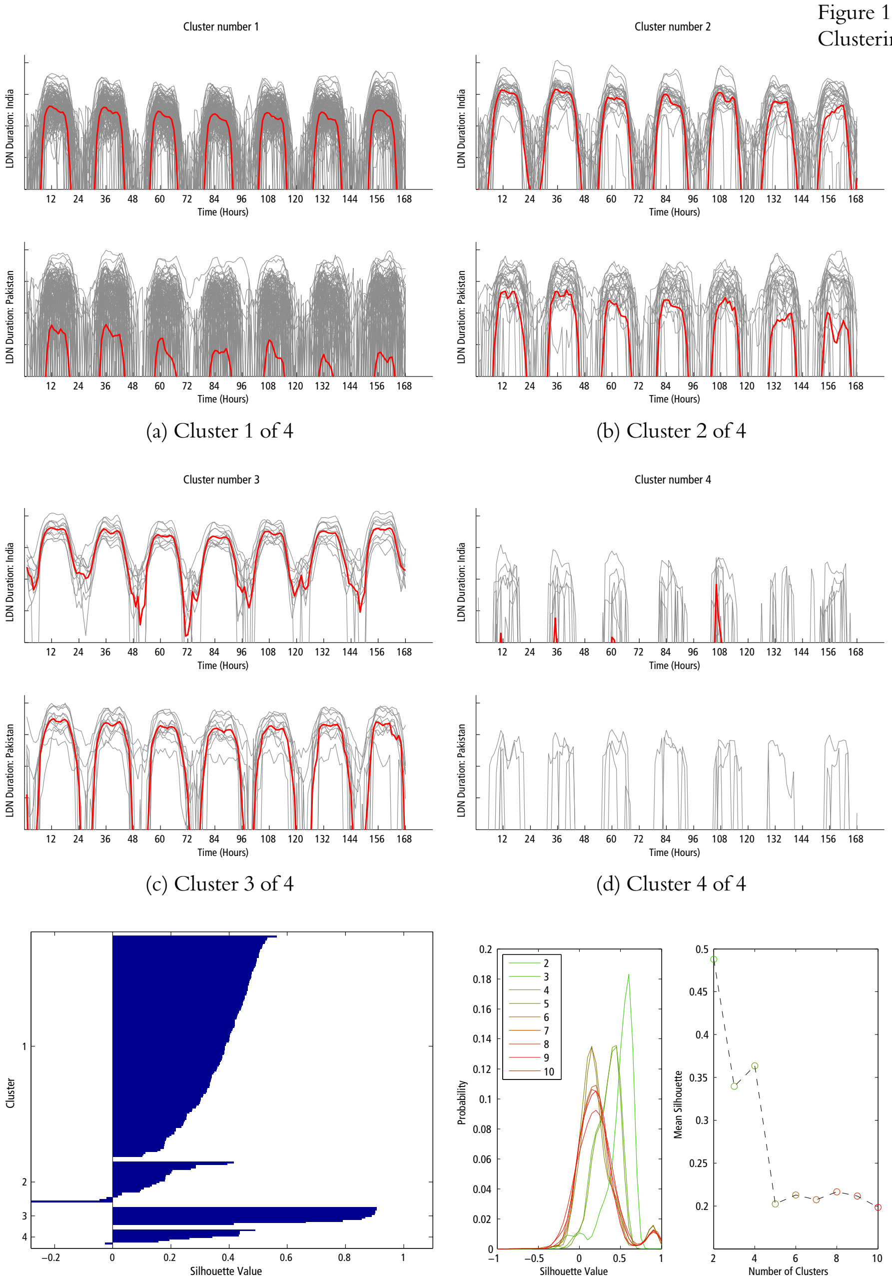


(e) Silhouette



(f) k-Means Selection

Figure 11.17: India & Pakistan Clustering



(a) Cluster 1 of 4

(b) Cluster 2 of 4

(c) Cluster 3 of 4

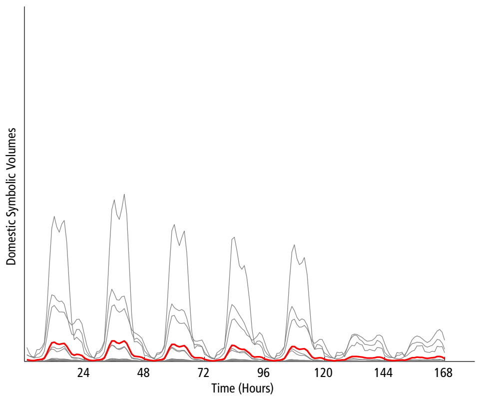
(d) Cluster 4 of 4

(e) Silhouette

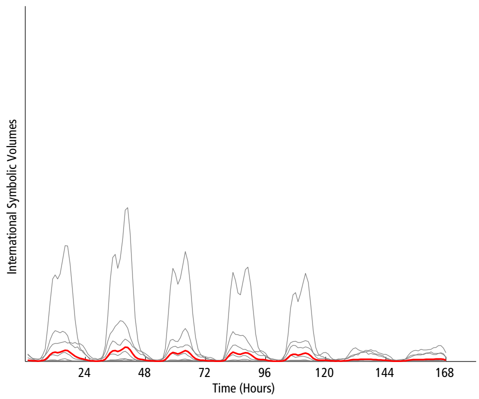
(f) k-Means Selection

11.3 Greater South East of England

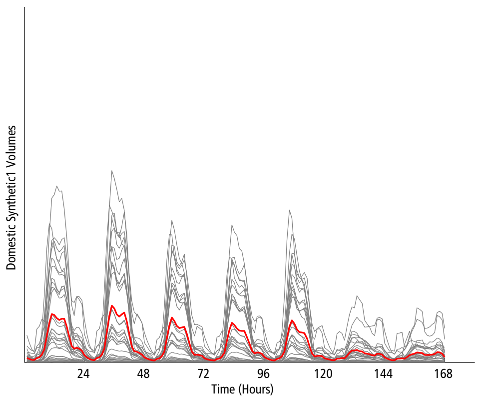
Average Signals at Significant Locations



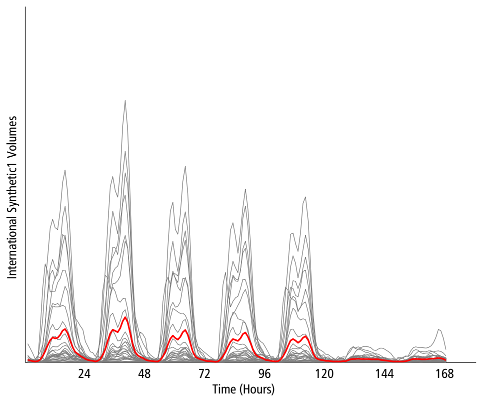
(a) Domestic Volumes (Symbolic)



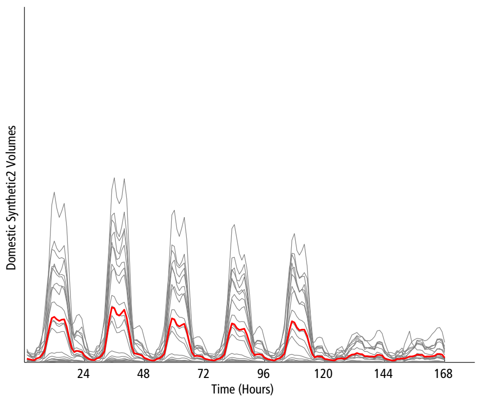
(b) International Volumes (Symbolic)



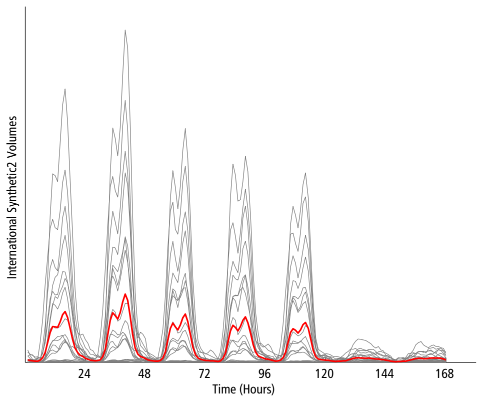
(c) Domestic Volumes (Synthetic 1)



(d) International Volumes (Synthetic 1)

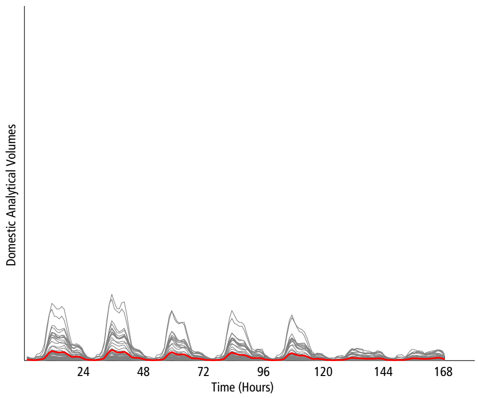


(e) Domestic Volumes (Synthetic 2)

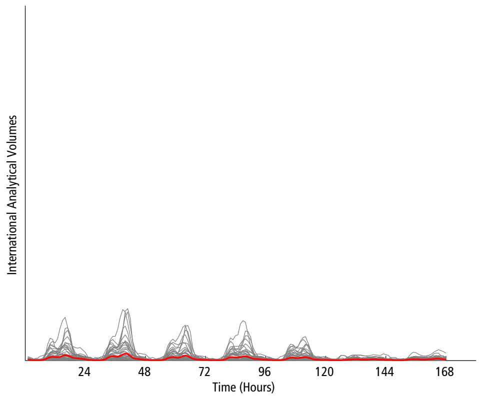


(f) International Volumes (Synthetic 2)

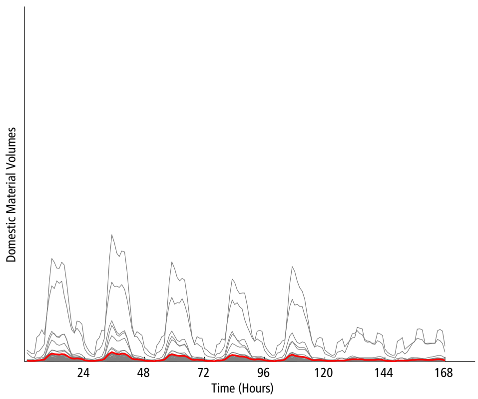
Figure 11.18: Signals by Significant Employment Areas (Part 1)



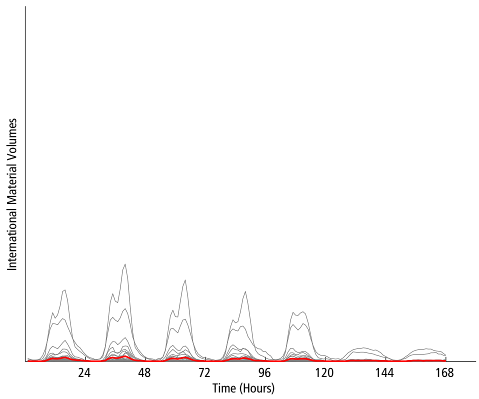
(a) Domestic Volumes (Analytical)



(b) International Volumes (Analytical)



(c) Domestic Volumes (Material)



(d) International Volumes (Material)

Figure 11.19: Signals by Significant Employment Areas (Part 2)

International & Domestic Clusters

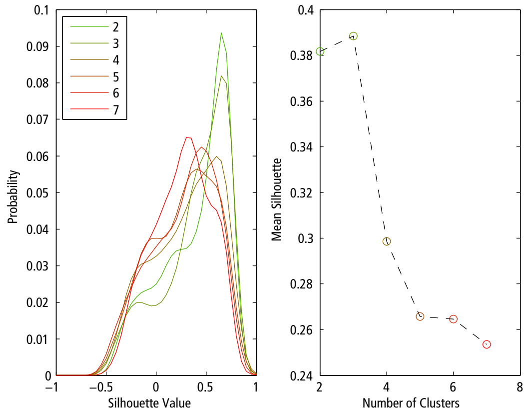
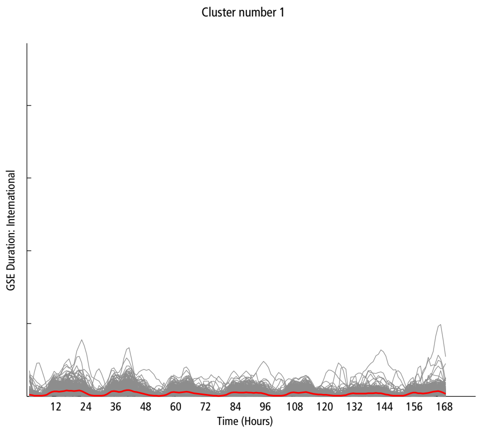
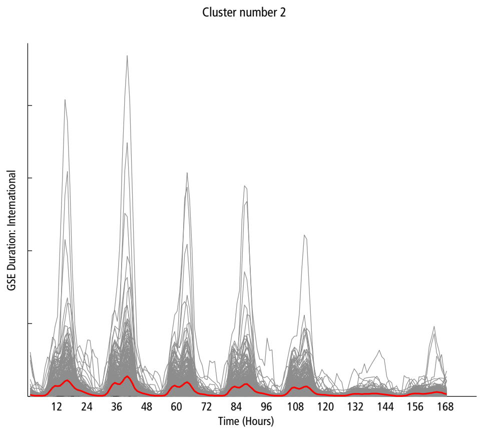
Selected International Features	Silhouette Test Results
Eigenvector 1, Eigenvector 2, Eigenvector 3, Eigenvector 4, Eigenvector 5, Eigenvector 6, Eigenvector 7, Eigenvector 8, Eigenvector 9, Eigenvector 10, Fourier Transform 1, Fourier Transform 2, Fourier Transform 8, Fourier Transform 26, Fourier Transform 33	

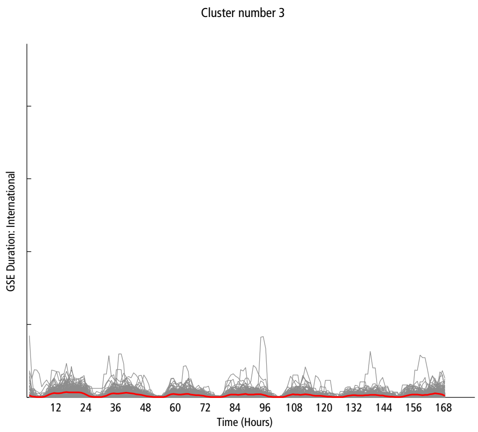
Table 11.1: International Eigenplace Classification



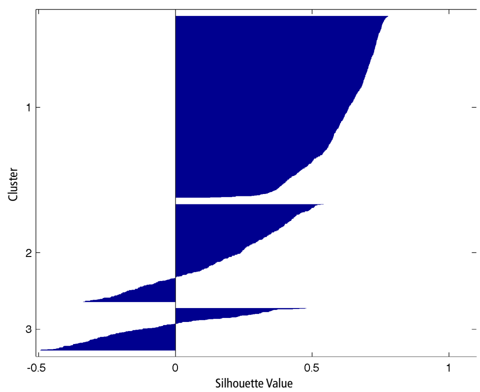
(a) Cluster 1 of 3



(b) Cluster 2 of 3



(c) Cluster 3 of 3



(d) Silhouette

Figure 11.20: International Eigenplace Signals

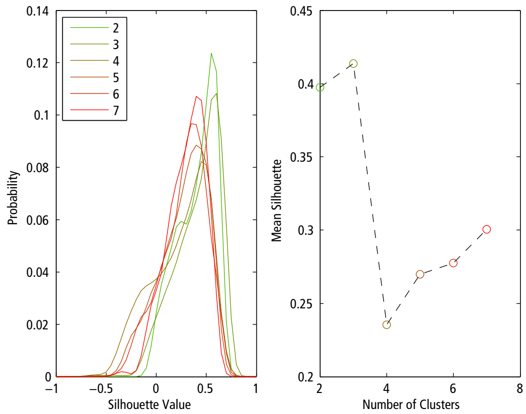
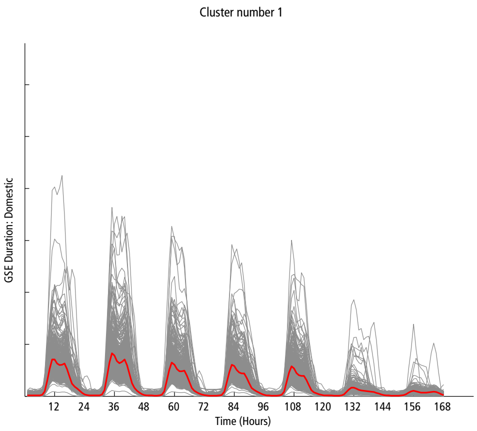
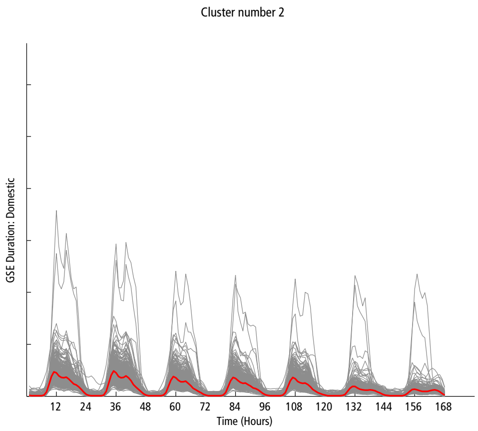
Selected Domestic Features	Silhouette Test Results
Eigenvector 2, Eigenvector 3, Eigenvector 4, Eigenvector 5, Eigenvector 6, Eigenvector 7, Eigenvector 8, Eigenvector 9, Eigenvector 10, Fourier Transform 1, Fourier Transform 2, Fourier Transform 3, Fourier Transform 6, Fourier Transform 8, Fourier Transform 9, Fourier Transform 10, Fourier Transform 15, Fourier Transform 22, Fourier Transform 29, Fourier Transform 32	

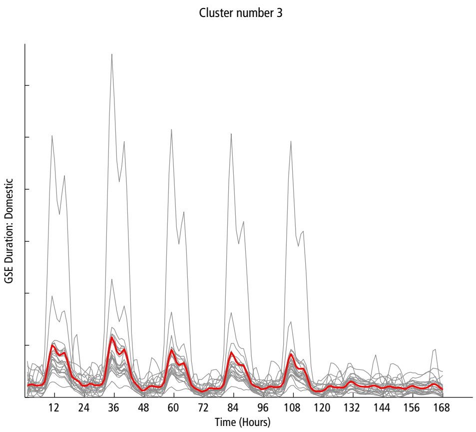
Table 11.2: Domestic Eigenplace Classification



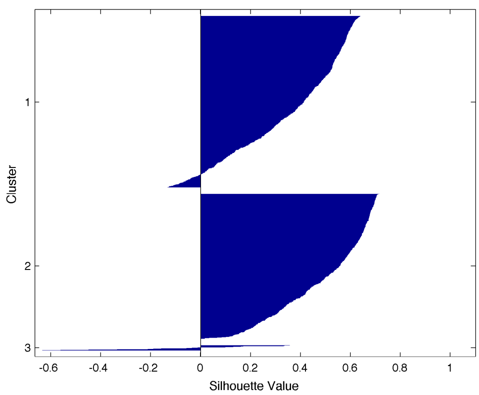
(a) Cluster 1 of 3



(b) Cluster 2 of 3



(c) Cluster 3 of 3



(d) Silhouette

Figure 11.21: Domestic Eigenplace Signals

Significant Employment Location Clusters

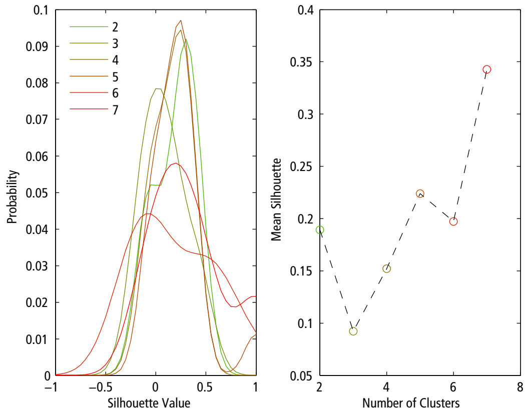
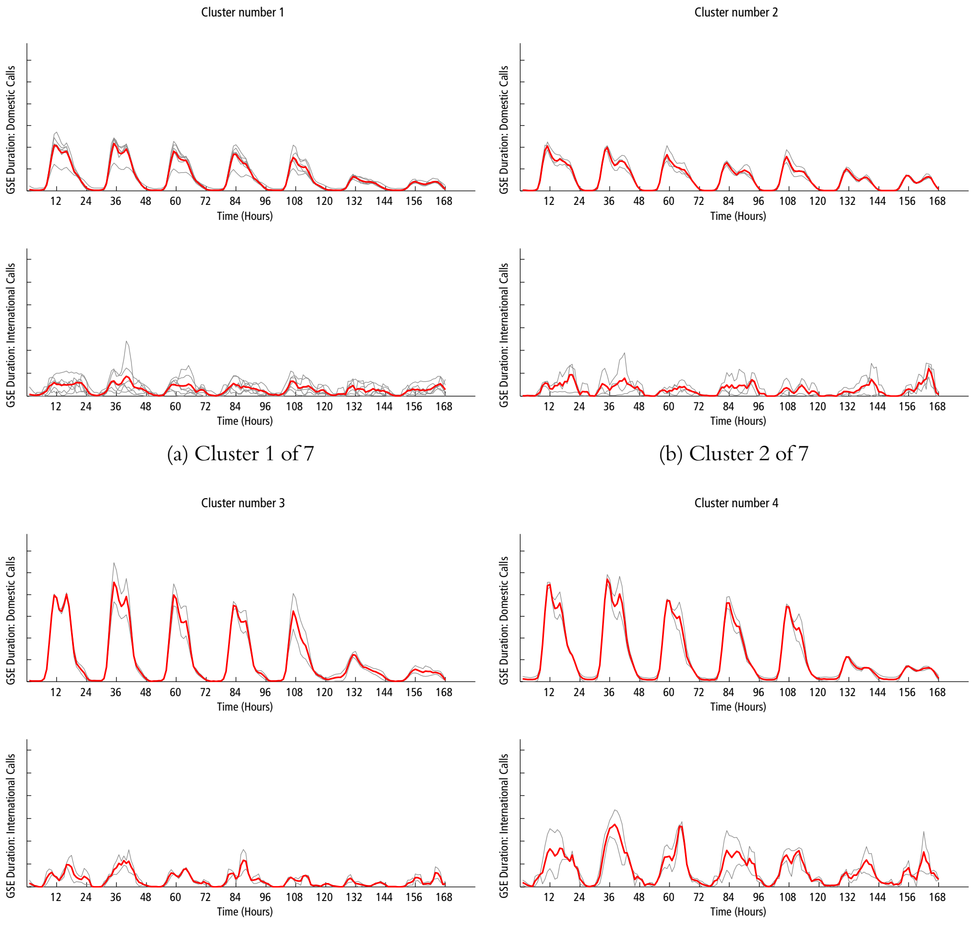
Selected Domestic Features	Selected International Features	Silhouette Test Results
Fourier Transform 1, Fourier Transform 2, Fourier Transform 3, Fourier Transform 6, Fourier Transform 8, Fourier Transform 9, Fourier Transform 15, Fourier Transform 25, Fourier Transform 29	Fourier Transform 1, Fourier Transform 8	

Table 11.3: Symbolic Eigenplace Classification



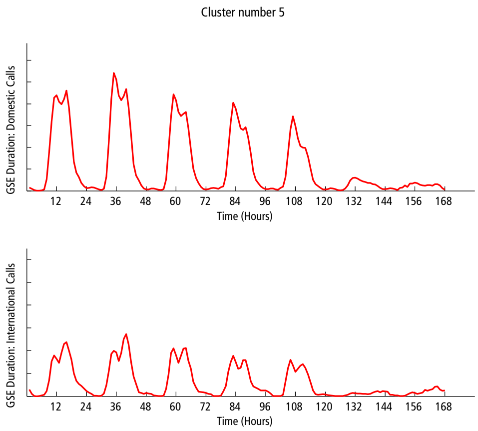
(a) Cluster 1 of 7

(b) Cluster 2 of 7

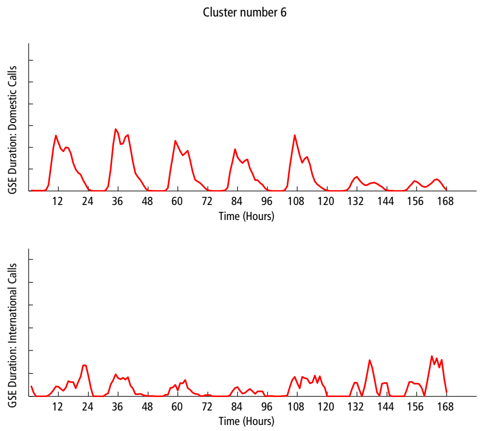
(c) Cluster 3 of 7

(d) Cluster 4 of 7

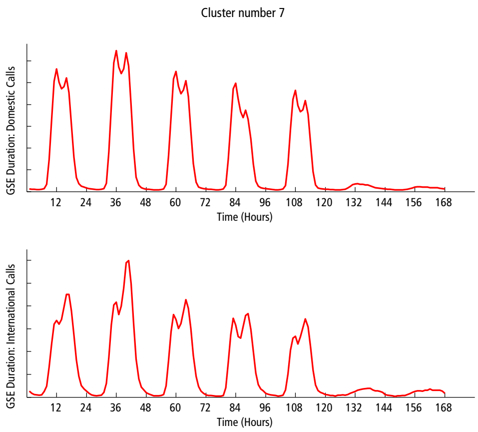
Figure 11.22: Symbolic Eigenplace Signals



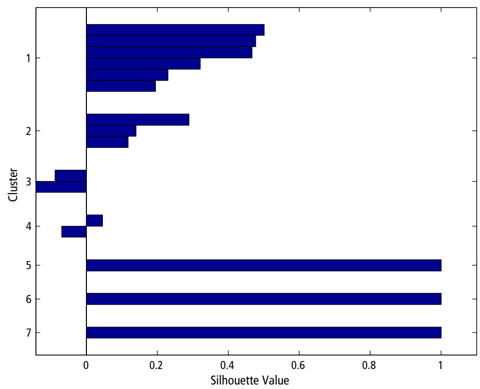
(a) Cluster 5 of 7



(b) Cluster 6 of 7



(c) Cluster 7 of 7



(d) Silhouette

Figure 11.23: Symbolic Eigenplace Signals

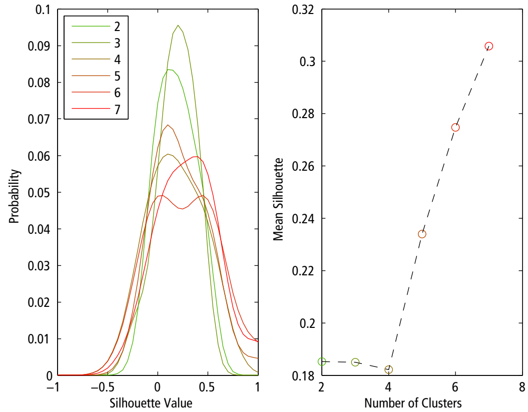
Selected Domestic Features	Selected Int'l Features	Number of Clusters Results
Eigenvector 2, Eigenvector 4, Eigenvector 5, Eigenvector 6, Eigenvector 10, Fourier Transform 1, Fourier Transform 2, Fourier Transform 3, Fourier Transform 4, Fourier Transform 5, Fourier Transform 6, Fourier Transform 7, Fourier Transform 8, Fourier Transform 9, Fourier Transform 10, Fourier Transform 11, Fourier Transform 13, Fourier Transform 14, Fourier Transform 15, Fourier Transform 17, Fourier Transform 22, Fourier Transform 23, Fourier Transform 24, Fourier Transform 27, Fourier Transform 28, Fourier Transform 29, Fourier Transform 30, Fourier Transform 31, Fourier Transform 32, Fourier Transform 34, Fourier Transform 35	Eigenvector 1, Eigenvector 8, Eigenvector 10, Fourier Transform 1, Fourier Transform 2, Fourier Transform 3, Fourier Transform 8, Fourier Transform 9, Fourier Transform 16, Fourier Transform 29	

Table 11.4: Synthetic Group 1 Eigenplace Classification

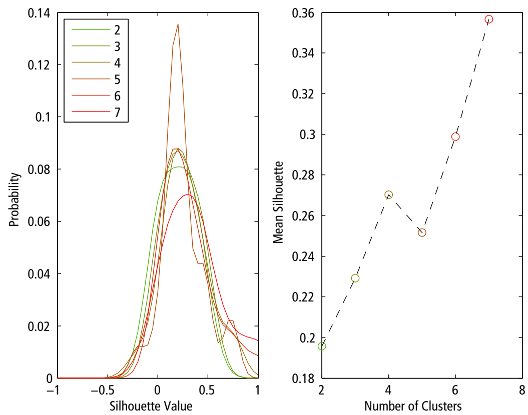
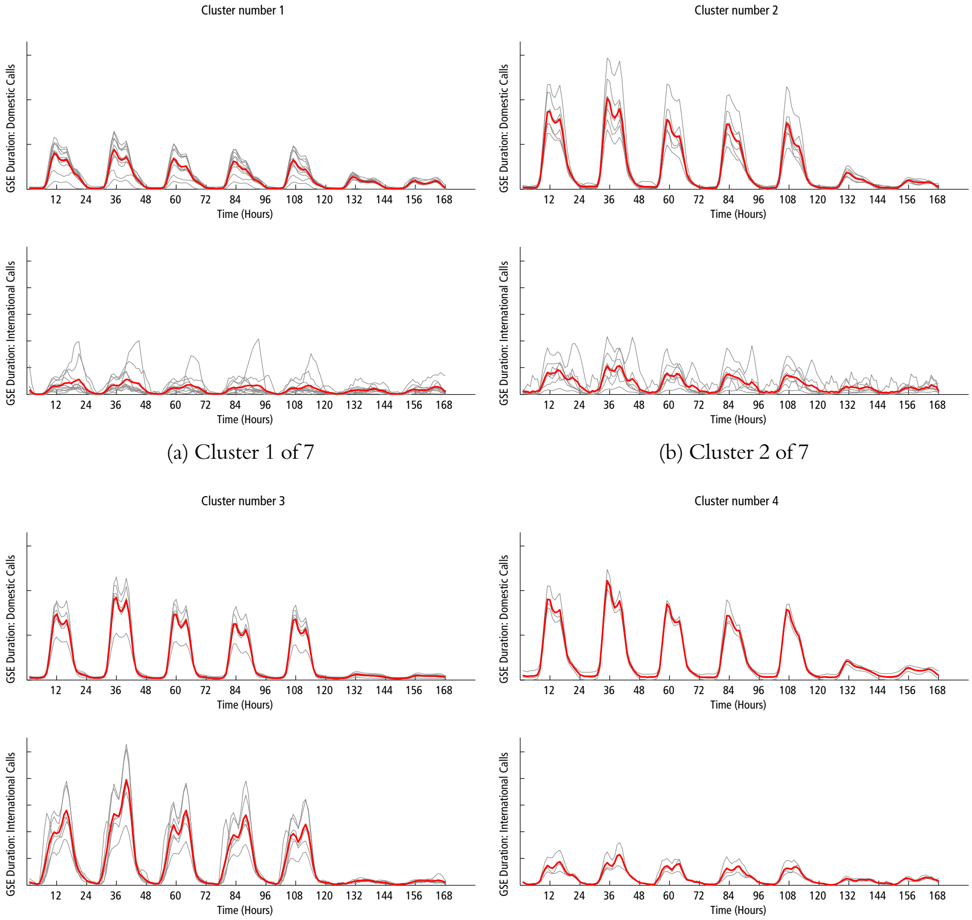
Selected Domestic Features	Selected Int'l Features	Number of Clusters Results
Eigenvector 6, Fourier Transform 1, Fourier Transform 2, Fourier Transform 3, Fourier Transform 6, Fourier Transform 8, Fourier Transform 9, Fourier Transform 10, Fourier Transform 15, Fourier Transform 25, Fourier Transform 29	Fourier Transform 1, Fourier Transform 2, Fourier Transform 8	

Table 11.5: Synthetic Group 2 Eigenplace Classification



(a) Cluster 1 of 7

(b) Cluster 2 of 7

(c) Cluster 3 of 7

(d) Cluster 4 of 7

Figure 11.24: Synthetic 1 Eigenplace Signals

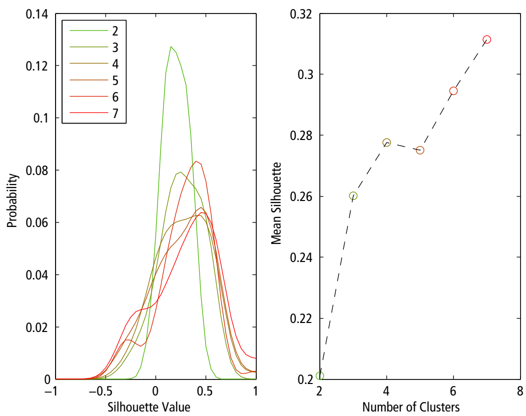
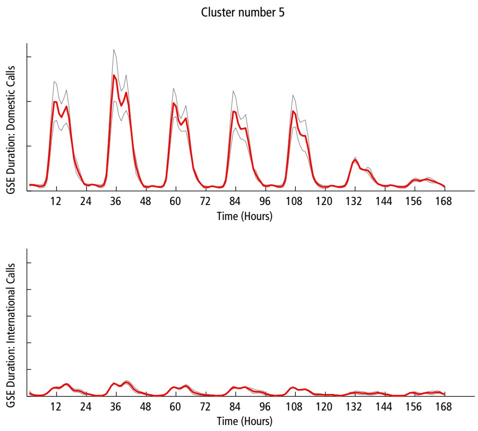
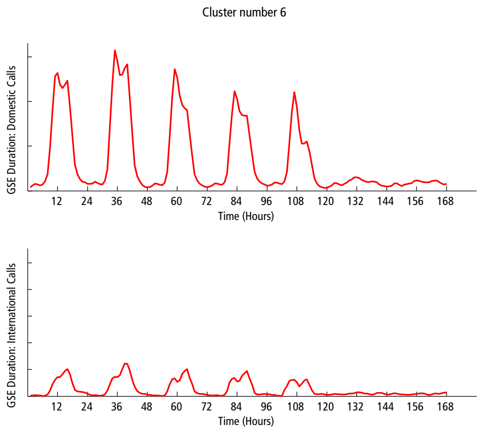
Selected Domestic Features	Selected Int'l Features	Number of Clusters Results
Eigenvector 3, Eigenvector 7, Fourier Transform 1, Fourier Transform 2, Fourier Transform 3, Fourier Transform 6, Fourier Transform 8, Fourier Transform 15, Fourier Transform 22, Fourier Transform 29, Fourier Transform 32	Eigenvector 2, Eigenvector 9, Fourier Transform 1, Fourier Transform 8	

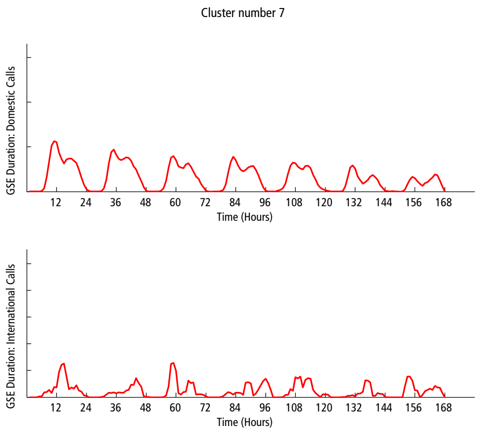
Table 11.6: Analytical Group Eigenplace Classification



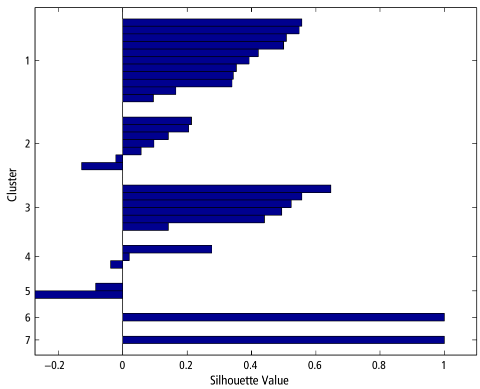
(a) Cluster 5 of 7



(b) Cluster 6 of 7

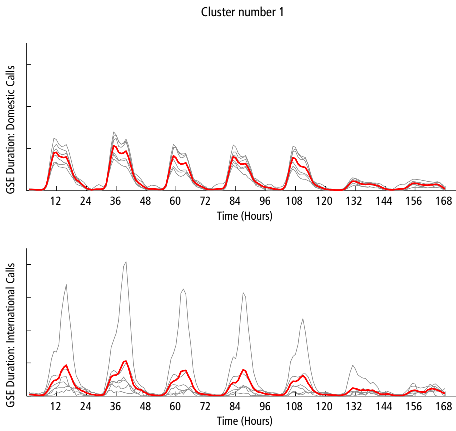


(c) Cluster 7 of 7

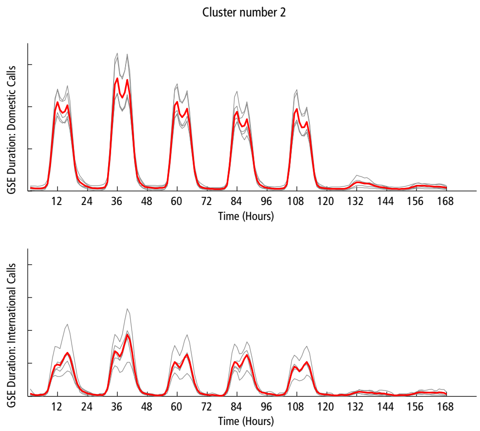


(d) Silhouette

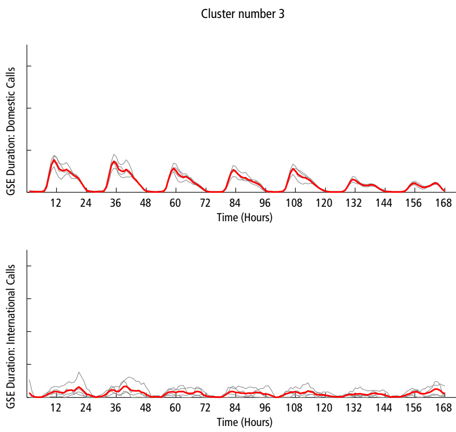
Figure 11.25: Synthetic 1 Eigenplace Signals (cont'd)



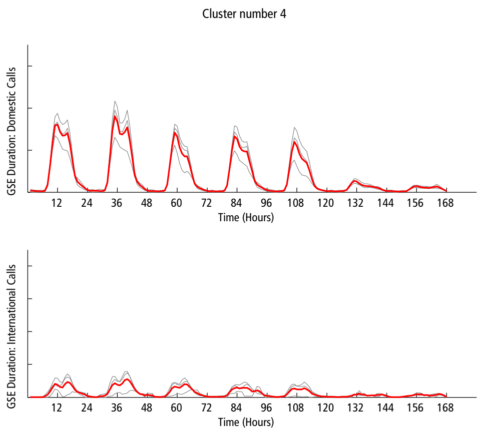
(a) Cluster 1 of 7



(b) Cluster 2 of 7

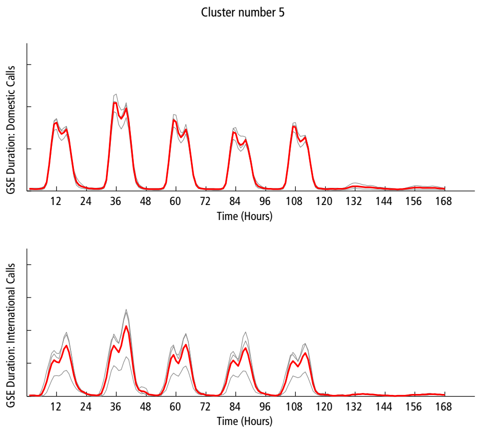


(c) Cluster 3 of 7

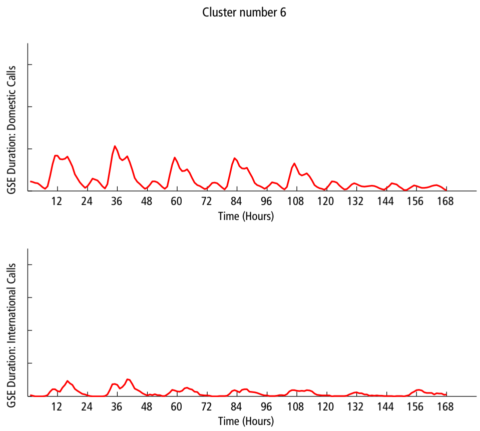


(d) Cluster 4 of 7

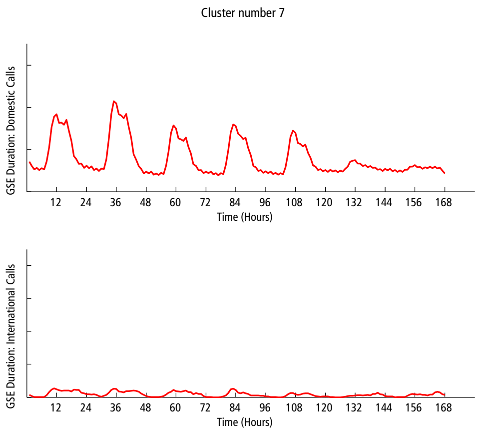
Figure 11.26: Synthetic 2 Eigenplace Signals



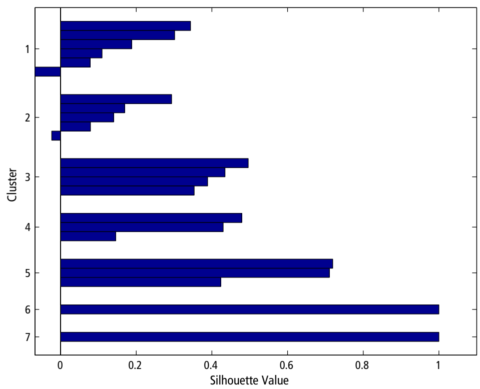
(a) Cluster 5 of 7



(b) Cluster 6 of 7

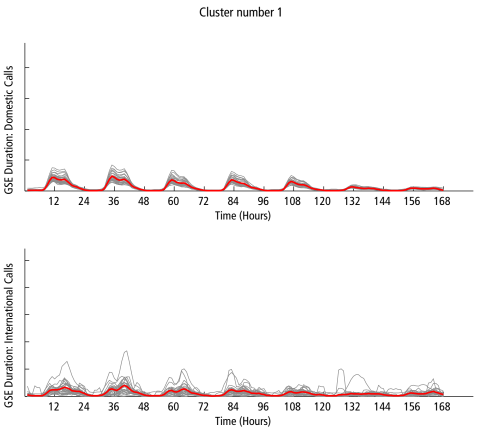


(c) Cluster 7 of 7

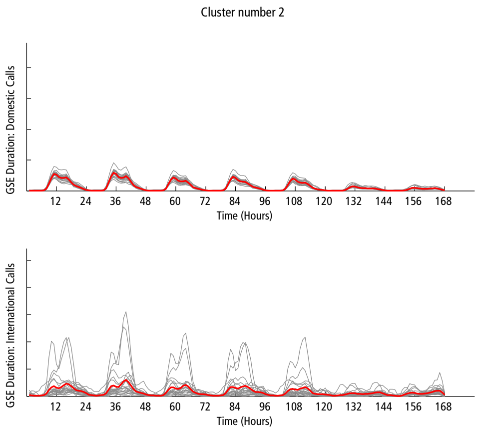


(d) Silhouette

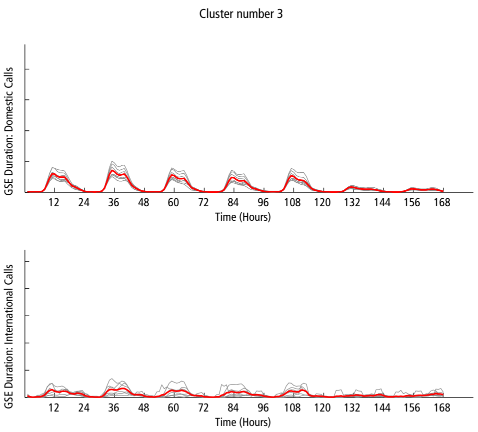
Figure 11.27: Synthetic 2 Eigenplace Signals (cont'd)



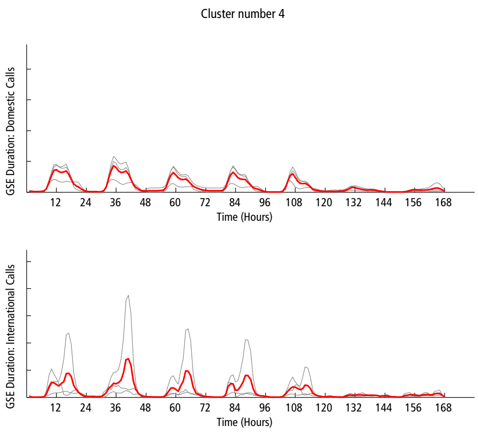
(a) Cluster 1 of 7



(b) Cluster 2 of 7

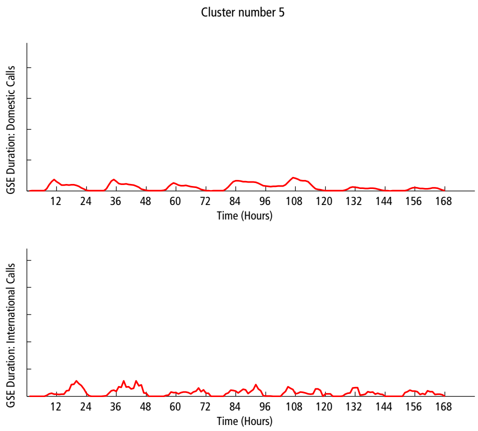


(c) Cluster 3 of 7

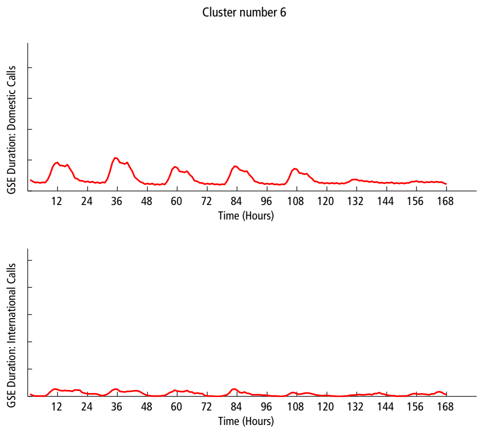


(d) Cluster 4 of 7

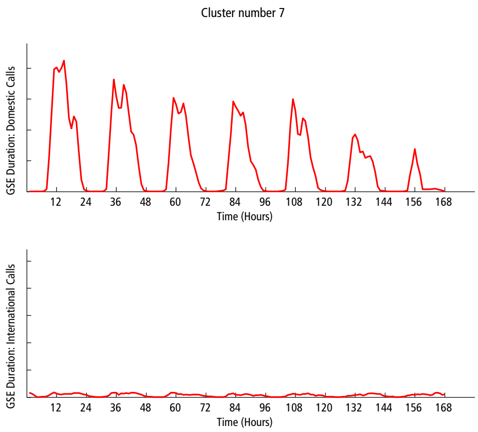
Figure 11.28: Analytical Eigenplace Signals



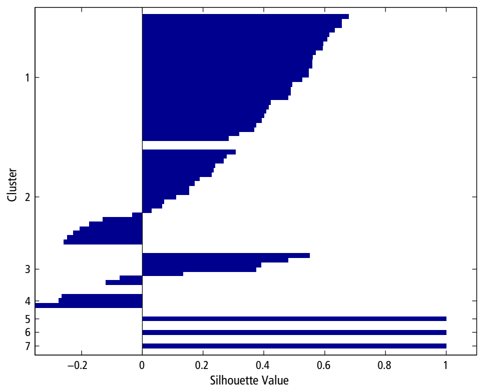
(a) Cluster 5 of 7



(b) Cluster 6 of 7



(c) Cluster 7 of 7



(d) Silhouette

Figure 11.29: Analytical Eigenplace Signals (cont'd)

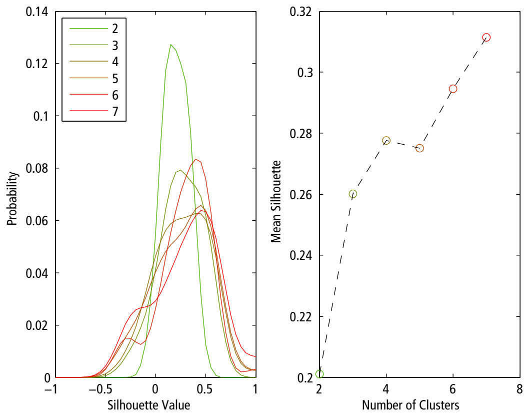
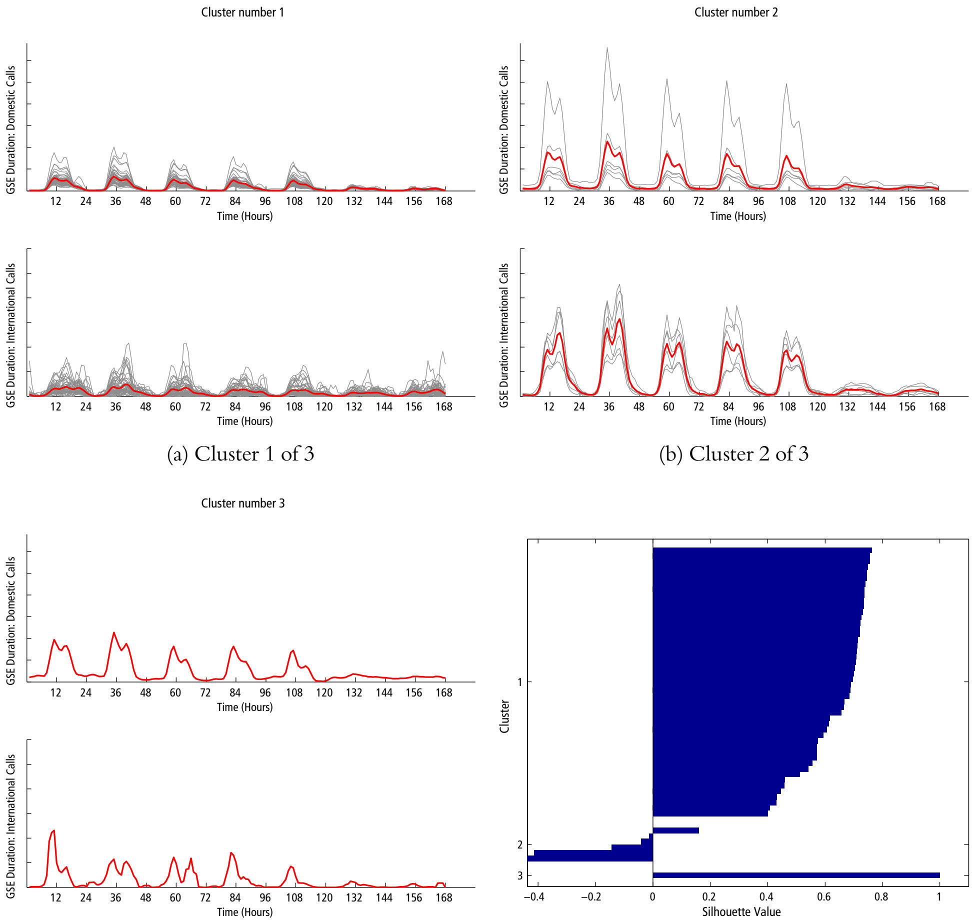
Selected Domestic Features	Selected Int’l Features	Number of Clusters Results
Eigenvector 2, Eigenvector 3, Eigenvector 4, Eigenvector 5, Eigenvector 6, Eigenvector 7, Eigenvector 8, Eigenvector 9, Eigenvector 10, Fourier Transform 1, Fourier Transform 2, Fourier Transform 3, Fourier Transform 4, Fourier Transform 5, Fourier Transform 6, Fourier Transform 7, Fourier Transform 8, Fourier Transform 9, Fourier Transform 10, Fourier Transform 11, Fourier Transform 13, Fourier Transform 14, Fourier Transform 15, Fourier Transform 17, Fourier Transform 18, Fourier Transform 20, Fourier Transform 22, Fourier Transform 23, Fourier Transform 24, Fourier Transform 25, Fourier Transform 26, Fourier Transform 27, Fourier Transform 28, Fourier Transform 29, Fourier Transform 30, Fourier Transform 31, Fourier Transform 34, Fourier Transform 35	Eigenvector 1, Eigenvector 2, Eigenvector 3, Eigenvector 5, Eigenvector 6, Eigenvector 8, Eigenvector 10, Fourier Transform 1, Fourier Transform 2, Fourier Transform 3, Fourier Transform 8, Fourier Transform 9	

Table 11.7: Material Flows Group Eigenplace Classification



(a) Cluster 1 of 3

(b) Cluster 2 of 3

(c) Cluster 3 of 3

(d) Silhouette

Figure 11.30: Material Flows Eigenplace Signals

KDDi Analysis of All Significant Areas

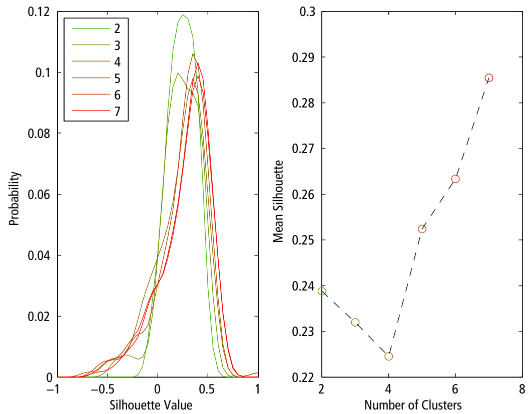
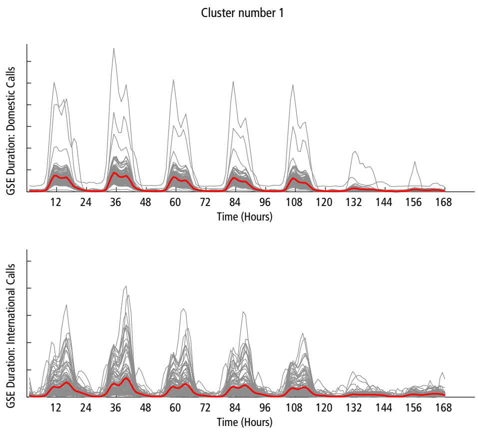
Selected Domestic Features	Selected Int'l Features	Number of Clusters Results
Clusters 1 & 2		
Eigenvector 2, Eigenvector 4, Eigenvector 5, Eigenvector 6, Fourier Transform 1, Fourier Transform 2, Fourier Transform 3, Fourier Transform 6, Fourier Transform 8, Fourier Transform 15, Fourier Transform 25, Fourier Transform 29	Eigenvector 2, Eigenvector 4, Eigenvector 5, Eigenvector 8, Eigenvector 9, Fourier Transform 1, Fourier Transform 8	

Table 11.8: Step 1: Feature Selection

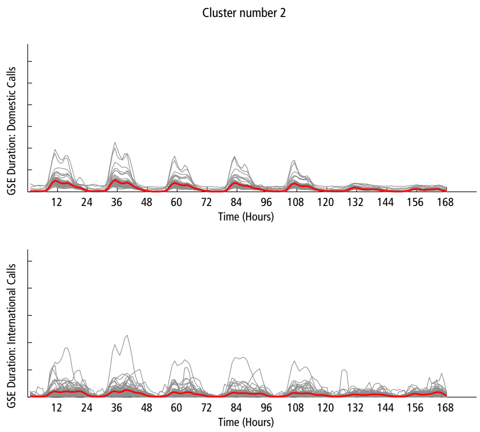
Residential Activity

We can also use the KDDi approach to explore residential geographies. Figure 11.35a creates two clusters which very obviously reflect PXAs with lesser (Cluster 1) and greater (Cluster 2) levels of calling to India and Pakistan. Taking *only* PXAs that were assigned to Cluster 2 in the first eigenplace analysis, we now pass this subset of PXAs through a new eigenplace process to generate the four-cluster map shown in Figure 11.35b.

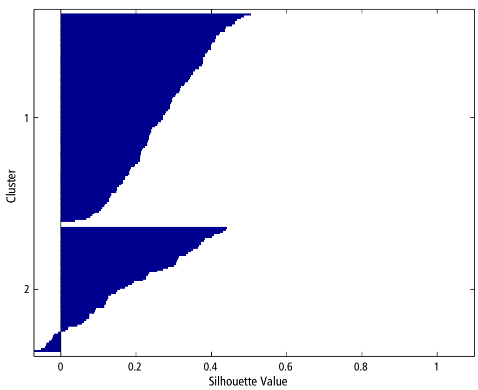
This multi-step approach enables us to tease out more fine-grained differences in the data since we have eliminated those PXAs that are not immediately relevant to the analysis. Comparing Figure 11.35b to Figure 11.11 shows that, in spite of the very different scales involved, the eigenplace analysis has picked out similar features and created similar clusters to those found at the London scale (see page 430). But at the GSE-scale we can now see how this forms part of a much larger distribution of households and businesses, with members of Cluster #4 also being identified in Norwich, Reading, and Slough.



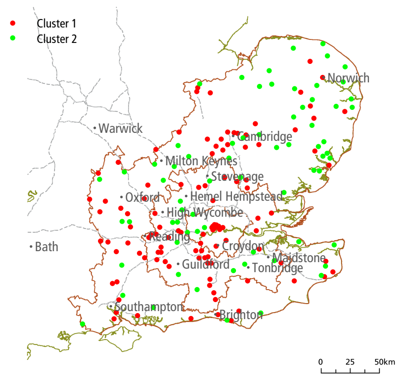
(a) Cluster 1 of 2



(b) Cluster 2 of 2



(c) Silhouette



(d) Cluster Map

Figure 11.31: Step 1: Signals & Silhouette

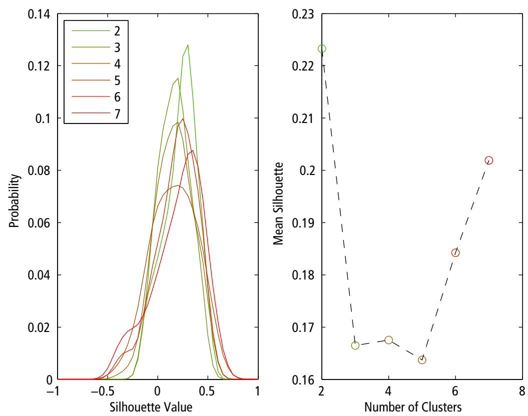
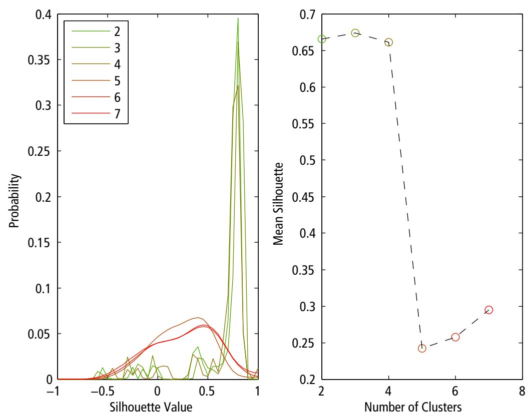
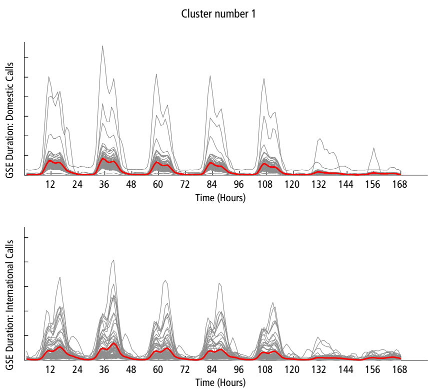
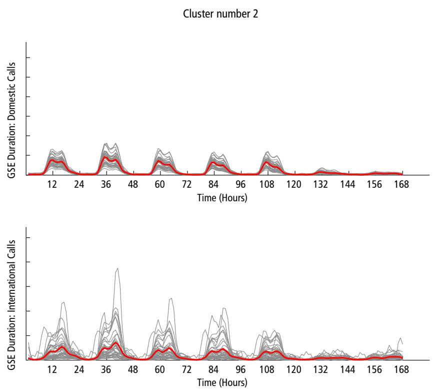
Selected Domestic Features	Selected Int'l Features	Number of Clusters Results
From Step 1, Cluster 1		
Eigenvector 2, Eigenvector 7, Eigenvector 9, Eigenvector 10, Fourier Transform 1, Fourier Transform 2, Fourier Transform 3, Fourier Transform 5, Fourier Transform 6, Fourier Transform 7, Fourier Transform 8, Fourier Transform 9, Fourier Transform 10, Fourier Transform 13, Fourier Transform 14, Fourier Transform 15, Fourier Transform 16, Fourier Transform 22, Fourier Transform 28, Fourier Transform 29, Fourier Transform 30, Fourier Transform 32	Eigenvector 3, Eigenvector 5, Eigenvector 8, Eigenvector 9, Fourier Transform 1, Fourier Transform 8	
From Step 1, Cluster 2		
Eigenvector 2, Eigenvector 6, Fourier Transform 1, Fourier Transform 2, Fourier Transform 3, Fourier Transform 8, Fourier Transform 15, Fourier Transform 22, Fourier Transform 29, Fourier Transform 32	Eigenvector 6, Eigenvector 7, Eigenvector 8, Eigenvector 9, Fourier Transform 1	

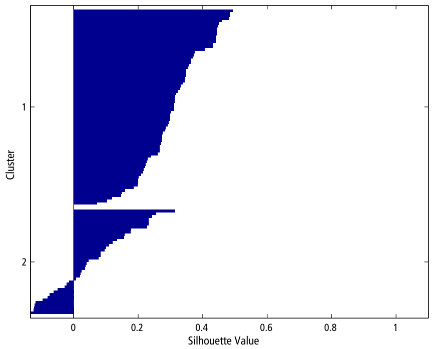
Table 11.9: Step 2: Feature Selection (Clusters 1 & 2)



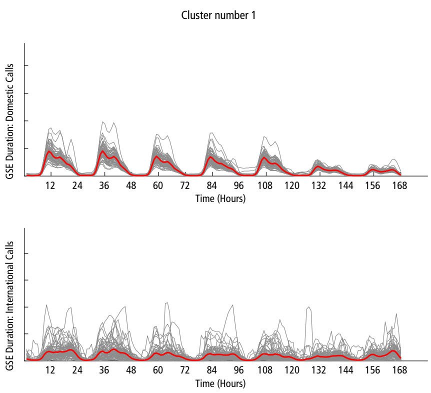
(a) Cluster 1 (from Step 1, Cluster 1)



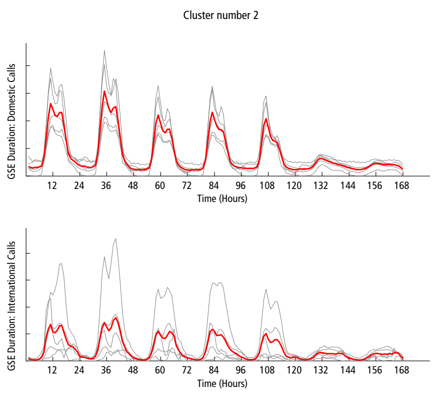
(b) Cluster 2 (from Step 1, Cluster 1)



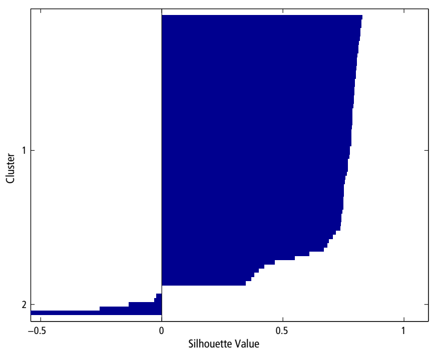
(c) Silhouette (from Step 1, Cluster 1)



(d) Cluster 3 (from Step 1, Cluster 2)



(e) Cluster 4 (from Step 1, Cluster 2)



(f) Silhouette (from Step 1, Cluster 2)

Figure 11.32: Step 2: Signals & Silhouette (Clusters 1 & 2)

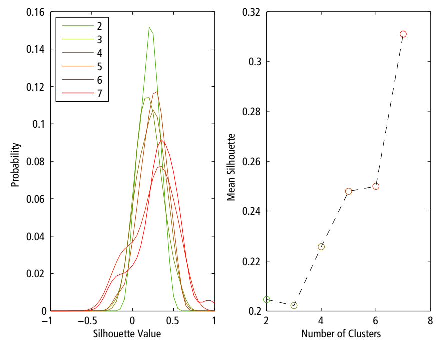
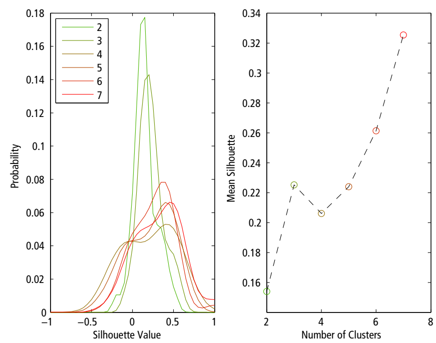
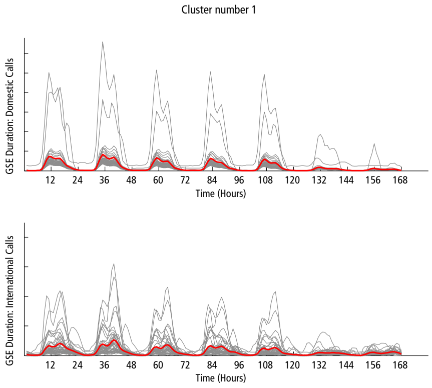
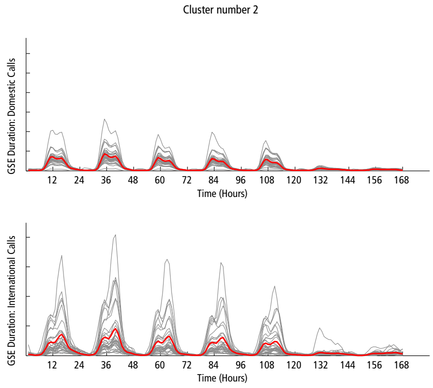
Selected Domestic Features	Selected Int'l Features	Number of Clusters Results
From Step 2, Cluster 1		
Eigenvector 2, Fourier Transform 1, Fourier Transform 2, Fourier Transform 3, Fourier Transform 6, Fourier Transform 7, Fourier Transform 8, Fourier Transform 9, Fourier Transform 15, Fourier Transform 29, Fourier Transform 32	Eigenvector 7, Fourier Transform 1, Fourier Transform 8	
From Step 2, Cluster 2		
Fourier Transform 1, Fourier Transform 2, Fourier Transform 3, Fourier Transform 6, Fourier Transform 7, Fourier Transform 8, Fourier Transform 9, Fourier Transform 10, Fourier Transform 15, Fourier Transform 16, Fourier Transform 26, Fourier Transform 29	Eigenvector 5, Fourier Transform 1, Fourier Transform 8	

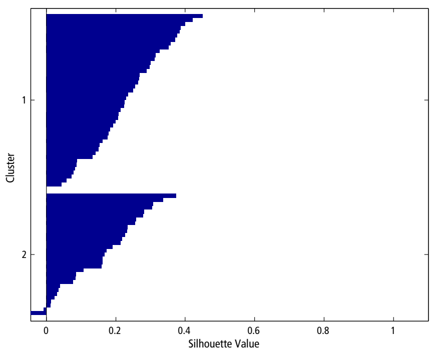
Table 11.10: Step 3a: Feature Selection (Clusters 1, 2, 3 & 4)



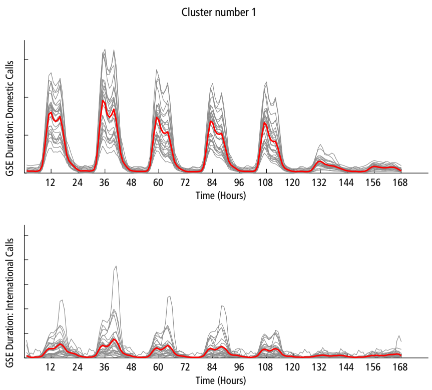
(a) Cluster 1 (from Step 2, Cluster 1)



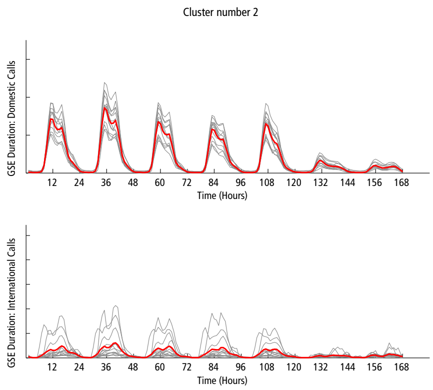
(b) Cluster 2 (from Step 2, Cluster 1)



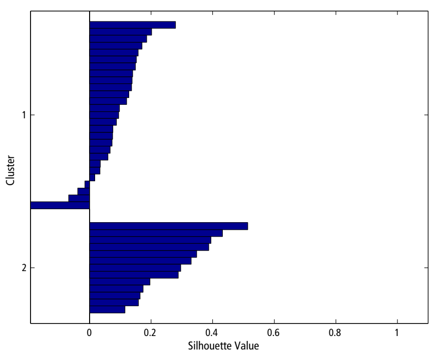
(c) Silhouette (from Step 2, Cluster 1)



(d) Cluster 3 (from Step 2, Cluster 2)



(e) Cluster 4 (from Step 2, Cluster 2)



(f) Silhouette (from Step 2, Cluster 2)

Figure 11.33: Step 3a: Signals & Silhouette (Clusters 1, 2, 3 & 4)

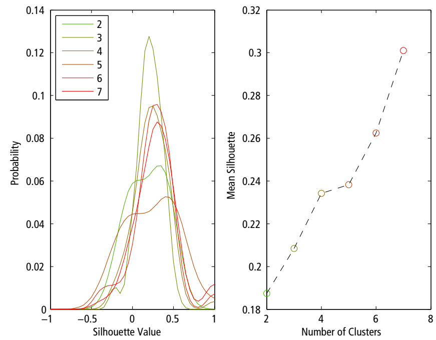
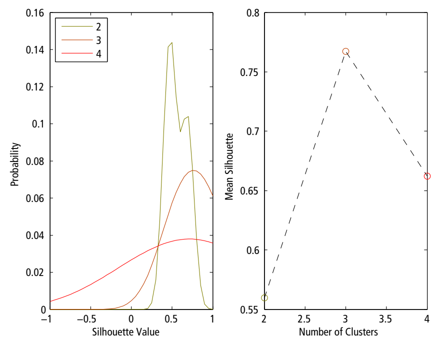
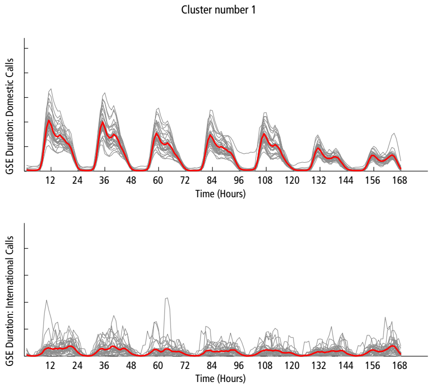
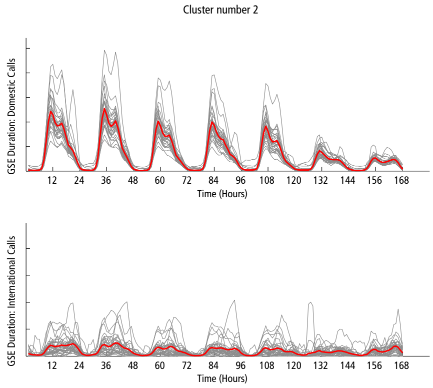
Selected Domestic Features	Selected Int'l Features	Number of Clusters Results
From Step 2, Cluster 3		
Eigenvector 4 Eigenvector 5 Eigenvector 9 Eigenvector 10 Fourier Transform 1 Fourier Transform 2 Fourier Transform 3 Fourier Transform 5 Fourier Transform 6 Fourier Transform 7 Fourier Transform 8 Fourier Transform 9 Fourier Transform 10 Fourier Transform 13 Fourier Transform 14 Fourier Transform 15 Fourier Transform 22 Fourier Transform 23 Fourier Transform 25 Fourier Transform 27 Fourier Transform 28 Fourier Transform 29	Eigenvector 2 Eigenvector 3 Eigenvector 4 Eigenvector 5 Eigenvector 6 Eigenvector 7 Eigenvector 8 Eigenvector 10 Fourier Transform 1 Fourier Transform 8	
From Step 2, Cluster 4		
Fourier Transform 1 Fourier Transform 2 Fourier Transform 3 Fourier Transform 6 Fourier Transform 7 Fourier Transform 8 Fourier Transform 10 Fourier Transform 13 Fourier Transform 15 Fourier Transform 26	Fourier Transform 1 Fourier Transform 2 Fourier Transform 3 Fourier Transform 8 Fourier Transform 9	

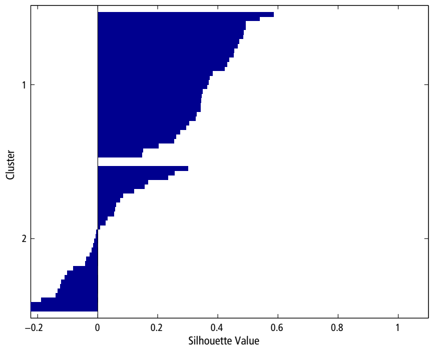
Table 11.11: Step 3b: Feature Selection (Clusters 5, 6, 7 & 8)



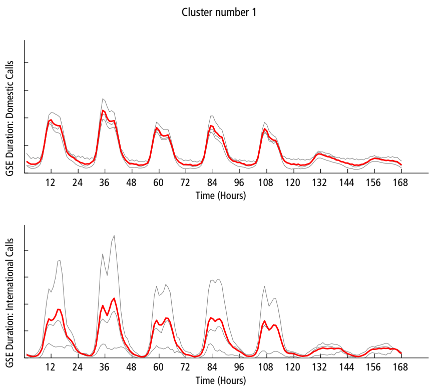
(a) Cluster 5 (from Step 2, Cluster 3)



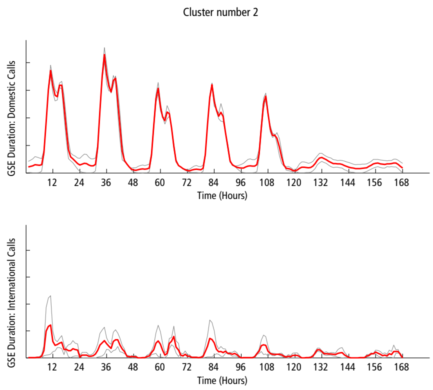
(b) Cluster 6 (from Step 2, Cluster 3)



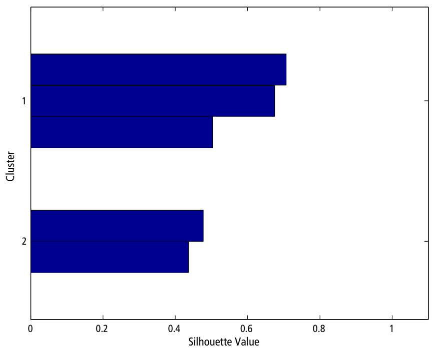
(c) Silhouette (from Step 2, Cluster 3)



(d) Cluster 7 (from Step 2, Cluster 4)



(e) Cluster 8 (from Step 2, Cluster 4)



(f) Silhouette (from Step 2, Cluster 4)

Figure 11.34: Step 3a: Signals & Silhouette (Clusters 5, 6, 7 & 8)

Suppressed from electronic copy at request of research partner

(a) Step 1: 2 Clusters

Suppressed from electronic copy at request of research partner

(b) Step 2: Subclustering from Step 1

Figure 11.35: India & Pakistan (Multi-Step Clustering)

11.4 Distance Decay by Significant Location

The figures on the following pages present the results from the simple gravity model presented on page 310 in which the predicted volume of telecommunications (measured in either minutes or calls) between two points is given by the equation:

$$V_{ij} = \alpha \,.\, \frac{P_i \times P_j}{d_{ij}^n}$$

P_i is the number of phones in PXA i and, similarly, P_j is the number of phones in PXA j. d is the distance between them, and this value then multiplied by a constant α to obtain the predicted flows.

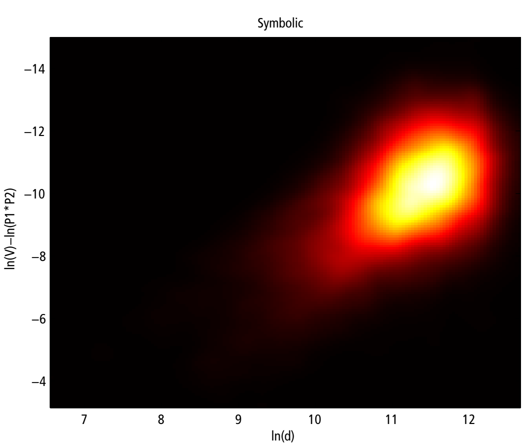
Since we have the total point-to-point flows and wish to understand how well this model fits the data, we can rearrange the gravity equation as follows:

$$\log \alpha - n \log d_{ij} = \log V_{ij} - \log (P_i \times P_j)$$

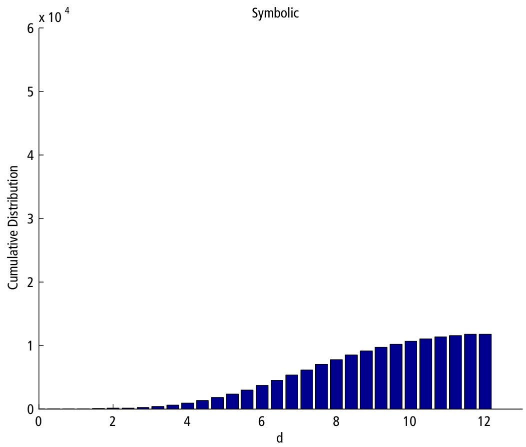
The y intercept is given by $\log \alpha$ and the slope of the line by n.

Rather than, as has historically been done by social network researchers, simply averaging the results over all places and all connections, I have below taken each of the groups of significant PXAs and have measured their interaction with every other PXA in the rest of the GSE region.

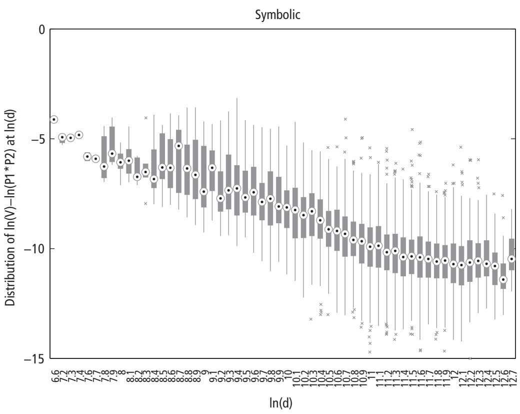
Every knowledge base and NOMIS group is presented in the same way: Figure 'A' presents the density of points in the relevant data set, where each point represents the interaction (in minutes) between two PXAs, one of which is an area of significant employment in the base or sector of interest; Figure 'B' provides a cumulative distribution over distance (in metres) to give a sense of how quickly communications accumulates; Figure 'C' takes the density values from 'A' and slices them into a series of boxplots to test the impact of the higher variance at the longer distances on the results; and, finally, Figure 'D' calculates the mean value for each distance slice (*i. e.* the noise is filtered out through the averaging process) with a regression line to provide a sense of goodness of fit.



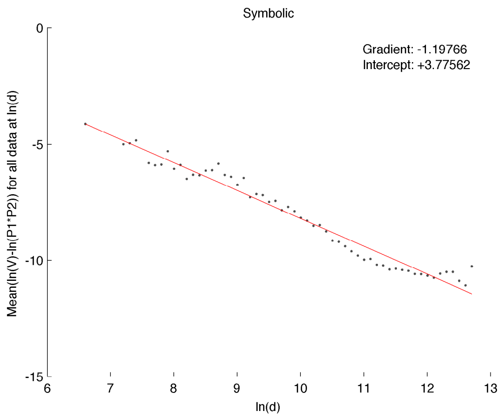
(a) Density



(b) Distribution

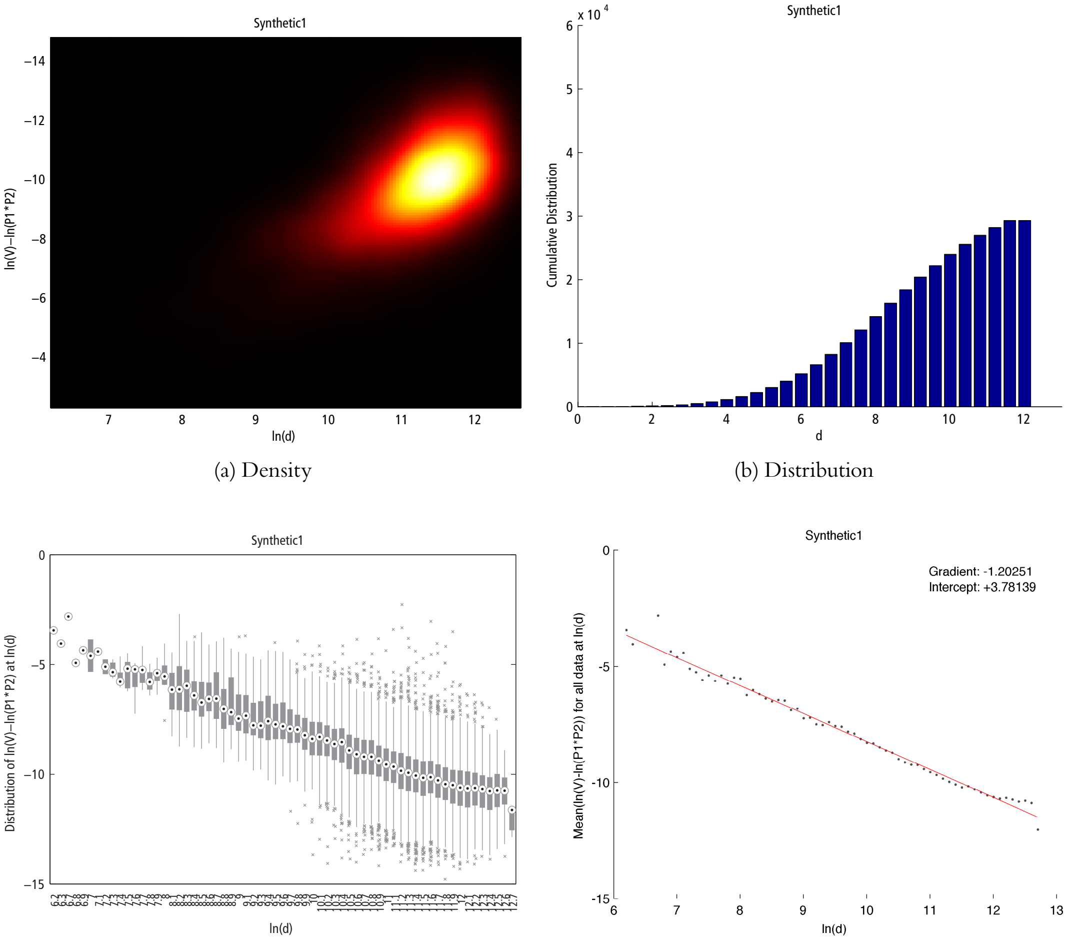


(c) Boxplot



(d) Fitted

Figure 11.36: Symbolic Distance Decay



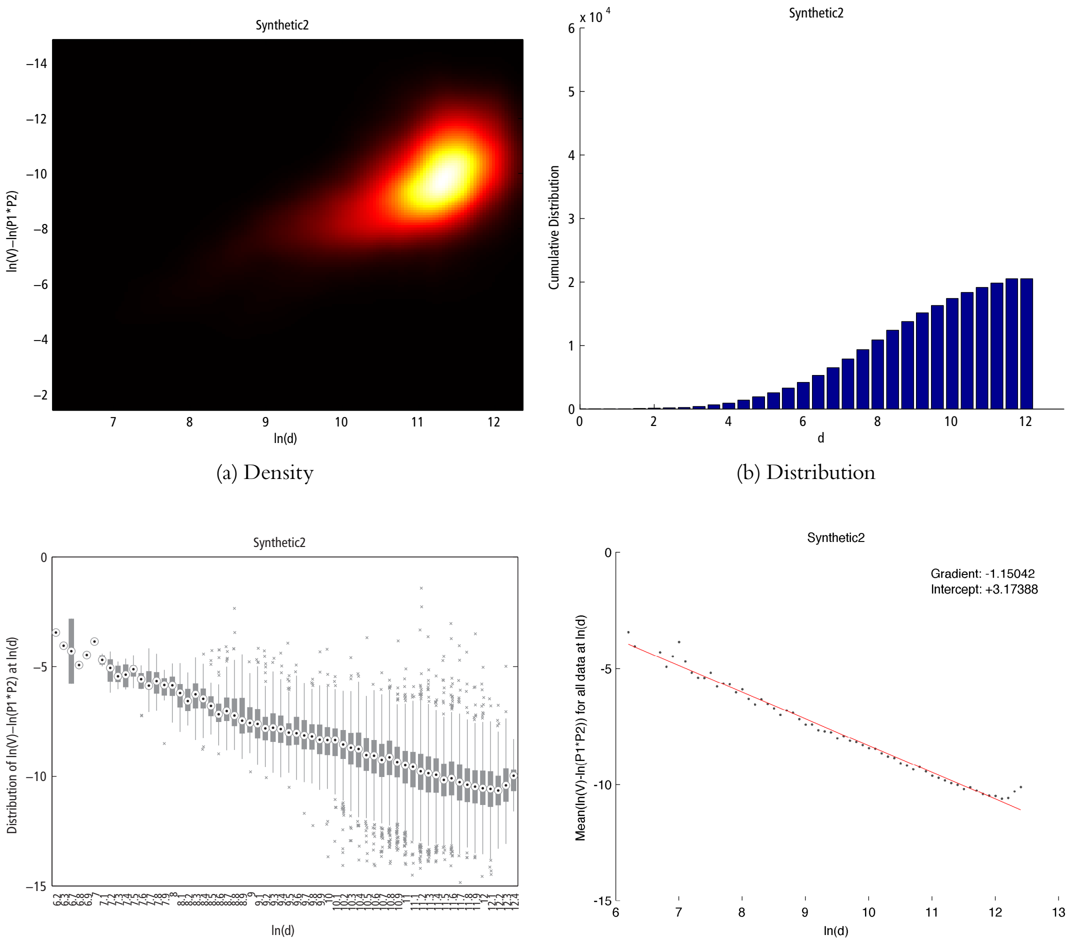
(a) Density

(b) Distribution

(c) Boxplot

(d) Fitted

Figure 11.37: Synthetic Group 1 Distance Decay



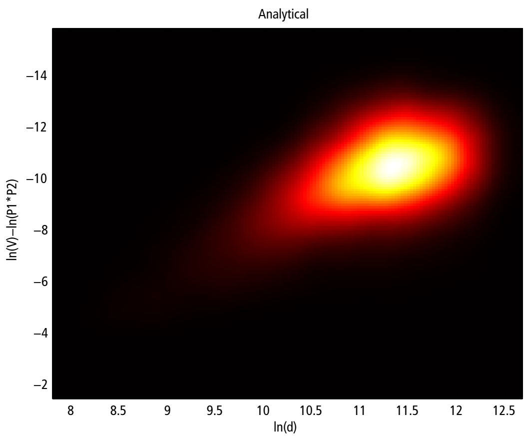
(a) Density

(b) Distribution

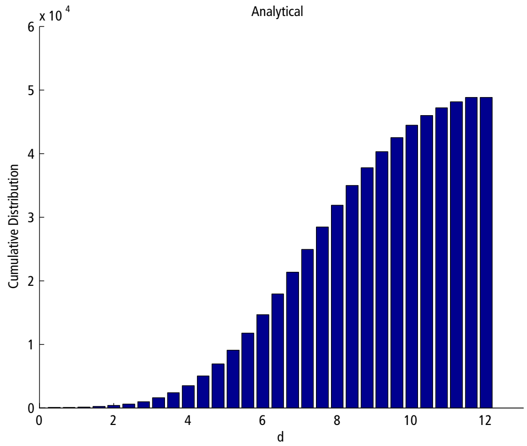
(c) Boxplot

(d) Fitted

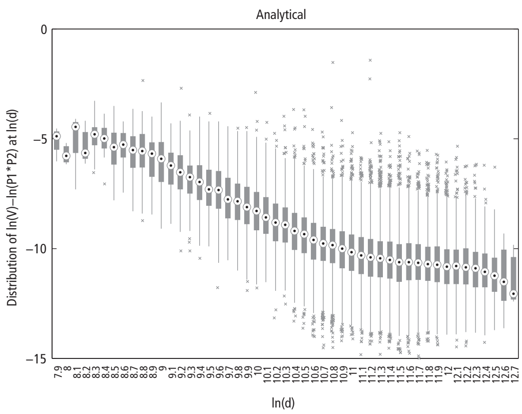
Figure 11.38: Synthetic Group 2 Distance Decay



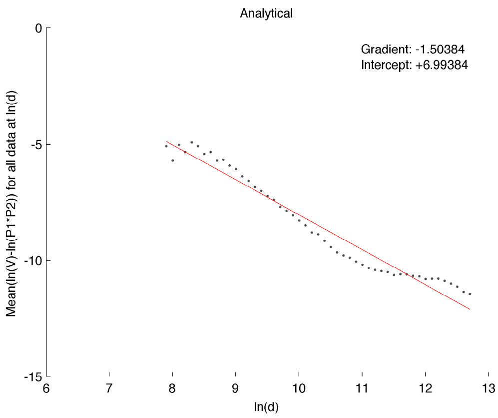
(a) Density



(b) Distribution

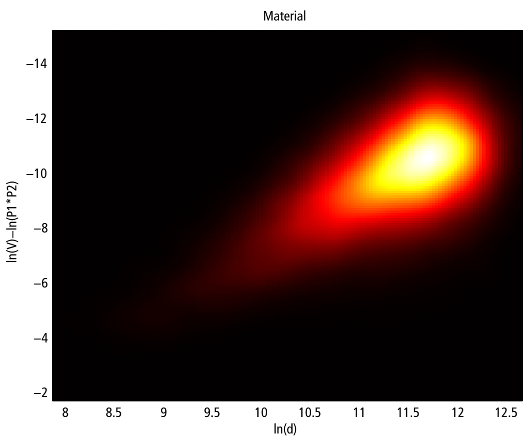


(c) Boxplot

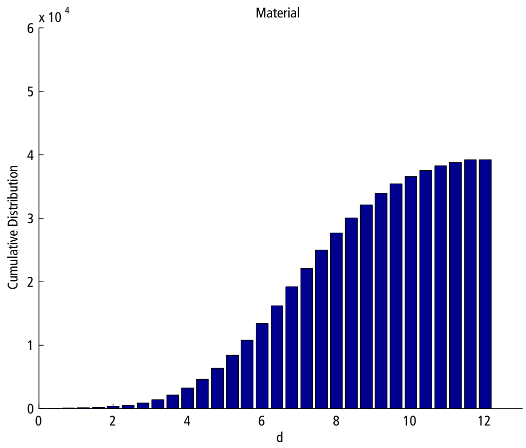


(d) Fitted

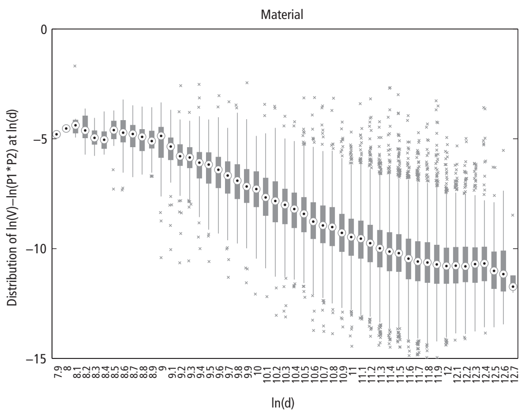
Figure 11.39: Analytical Distance Decay



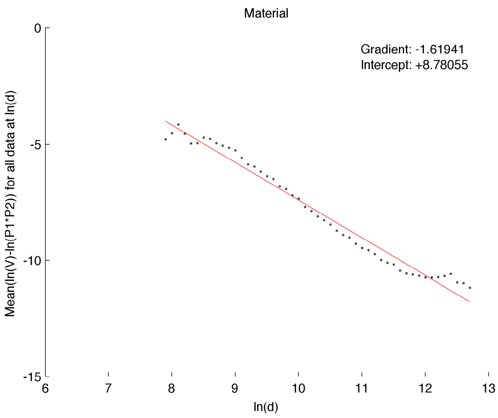
(a) Density



(b) Distribution

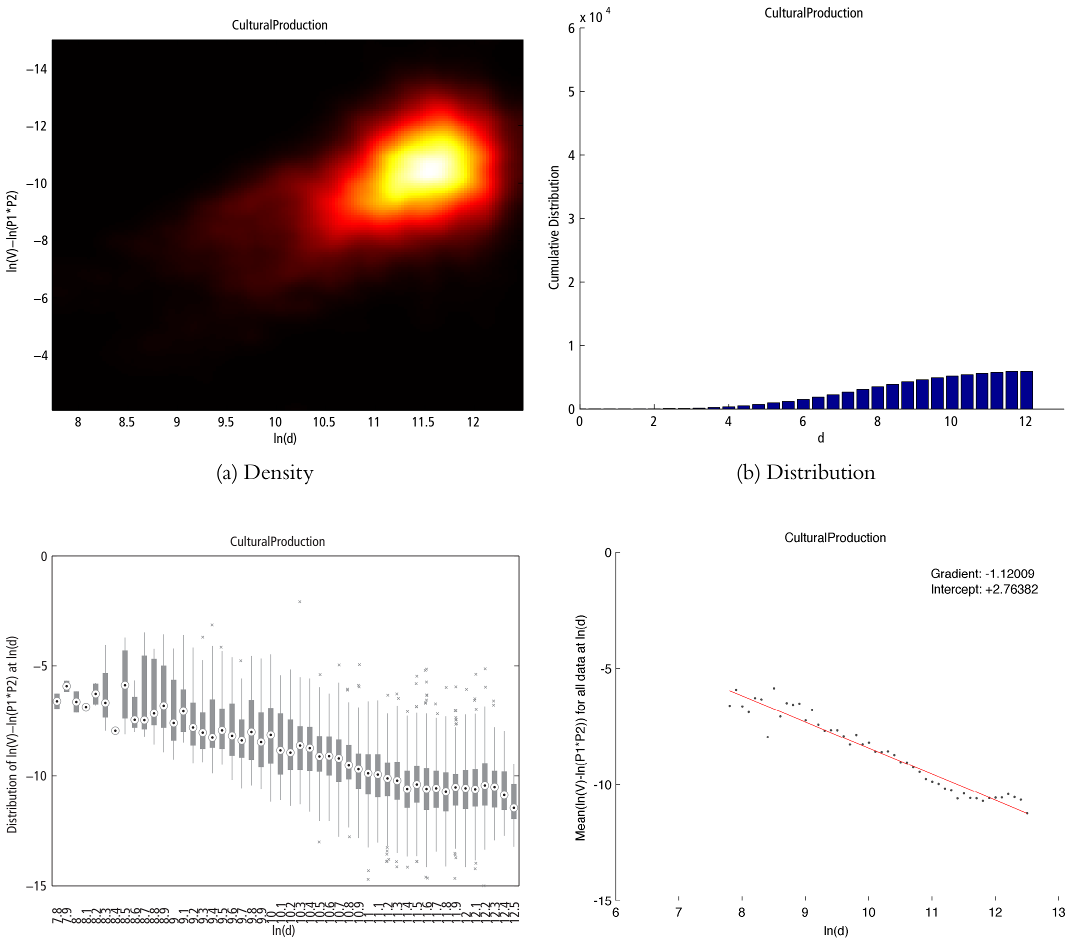


(c) Boxplot



(d) Fitted

Figure 11.40: Material Distance Decay



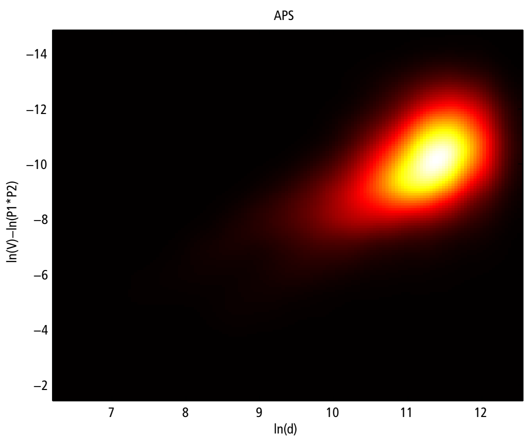
(a) Density

(b) Distribution

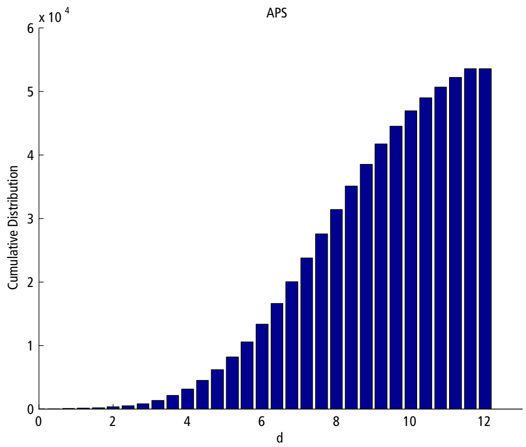
(c) Boxplot

(d) Fitted

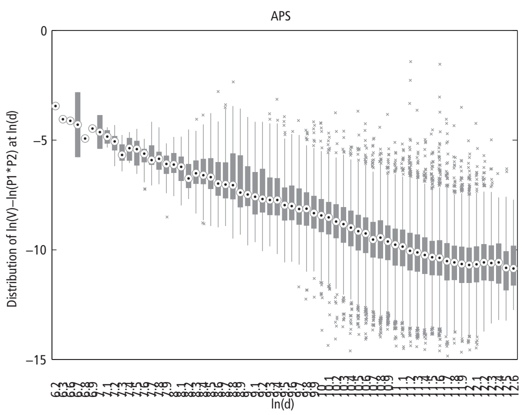
Figure 11.41: Cultural Production Distance Decay



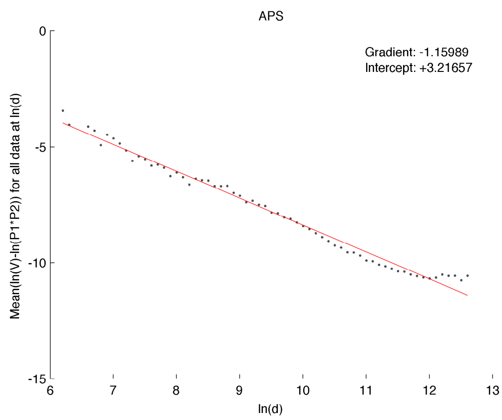
(a) Density



(b) Distribution

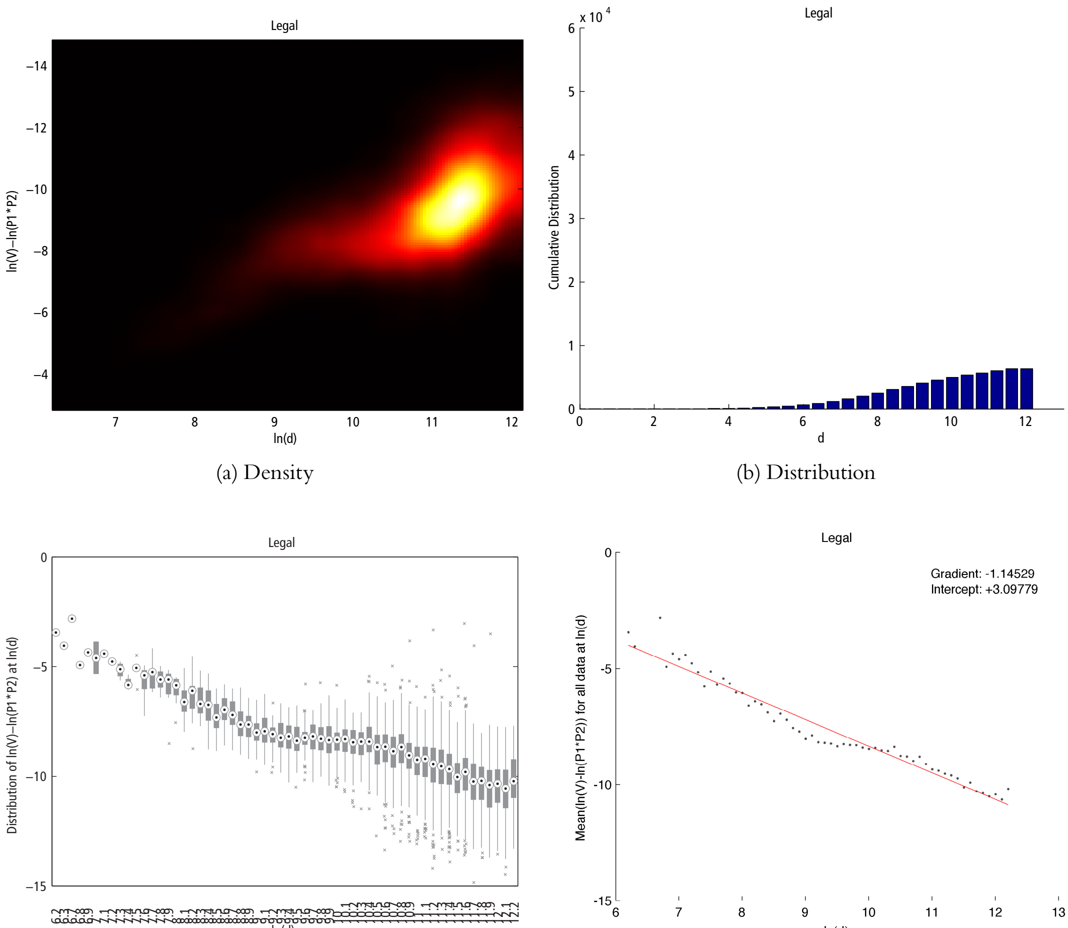


(c) Boxplot



(d) Fitted

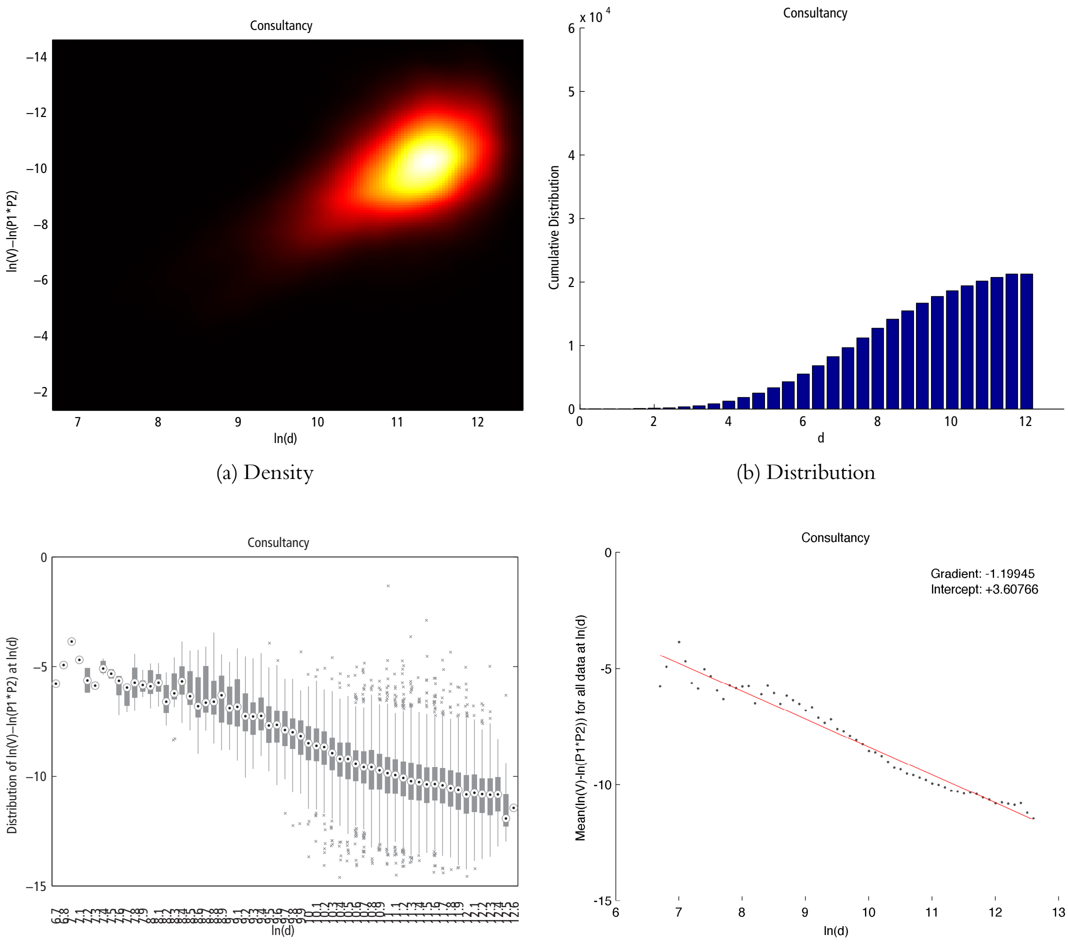
Figure 11.42: APS Distance Decay



(a) Density (b) Distribution

(c) Boxplot (d) Fitted

Figure 11.43: Legal & Accountancy Distance Decay



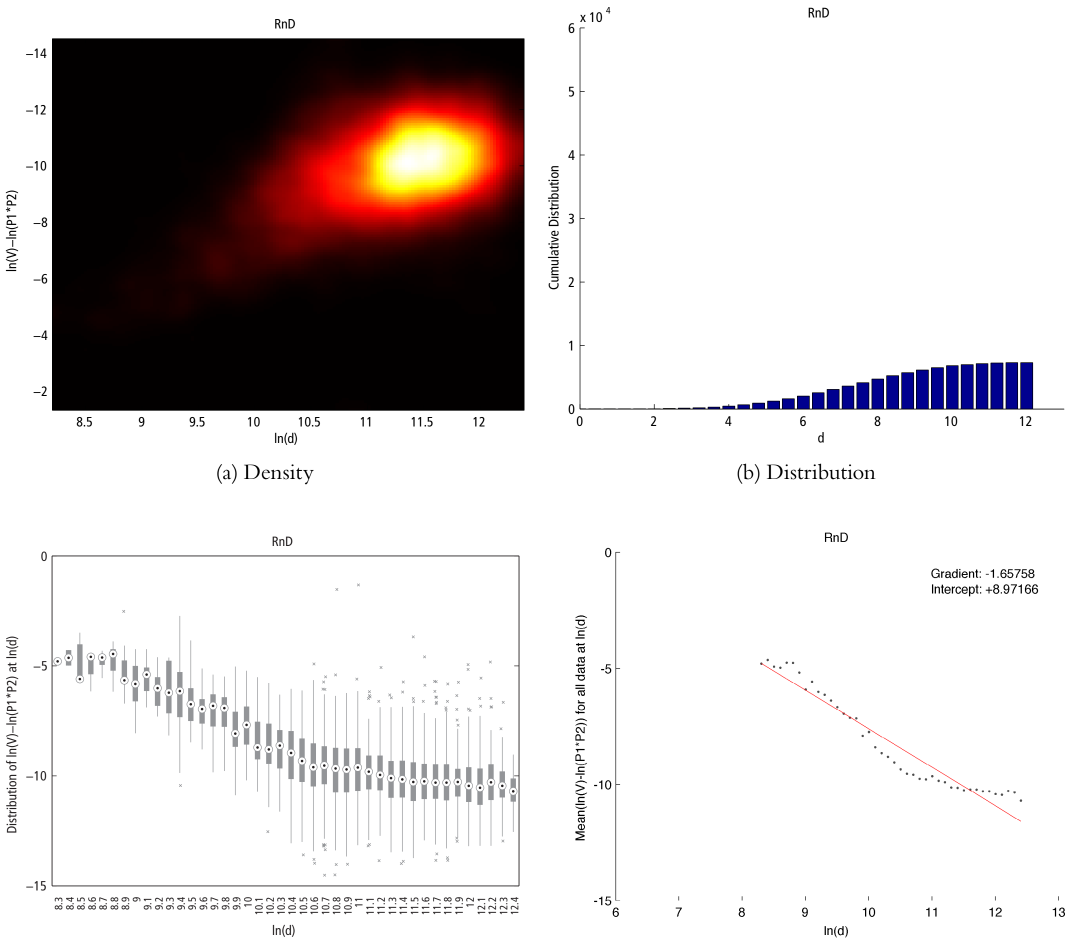
(a) Density

(b) Distribution

(c) Boxplot

(d) Fitted

Figure 11.44: Consultancy Distance Decay



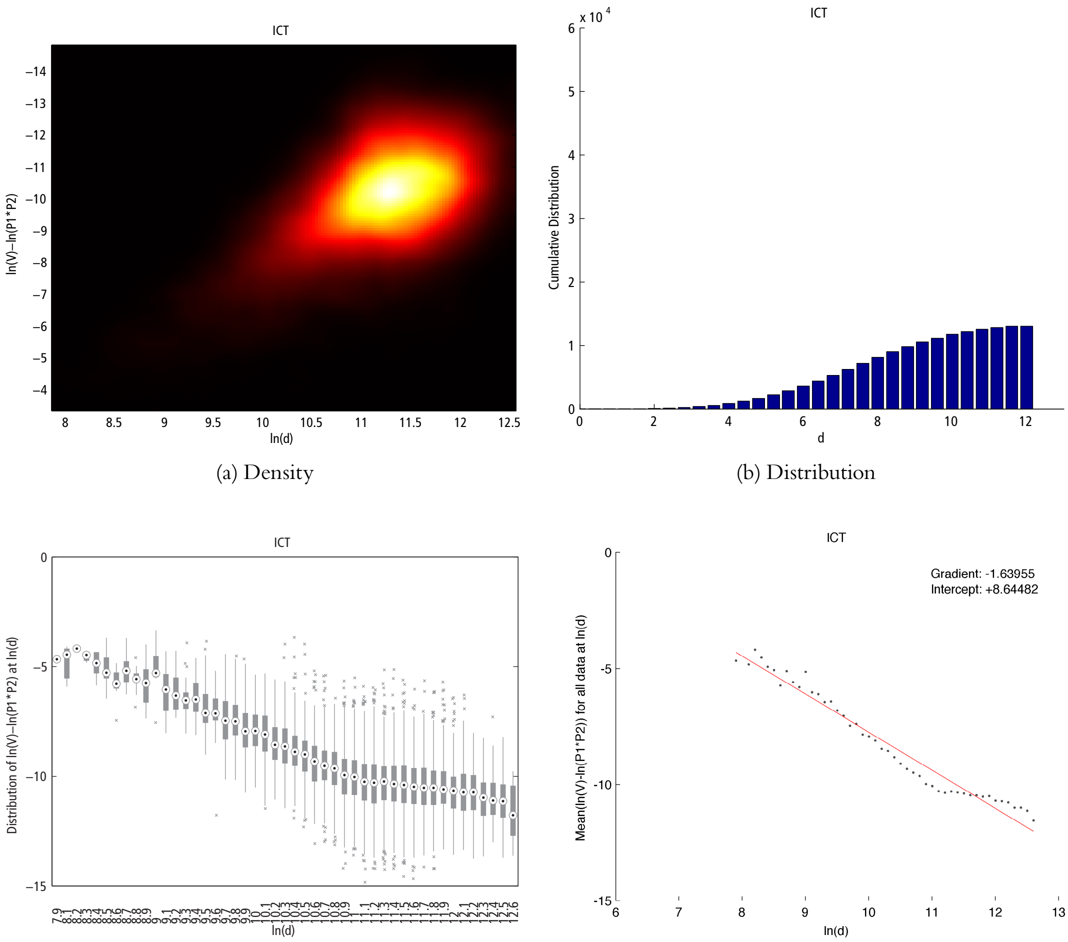
(a) Density

(b) Distribution

(c) Boxplot

(d) Fitted

Figure 11.45: R&D Distance Decay



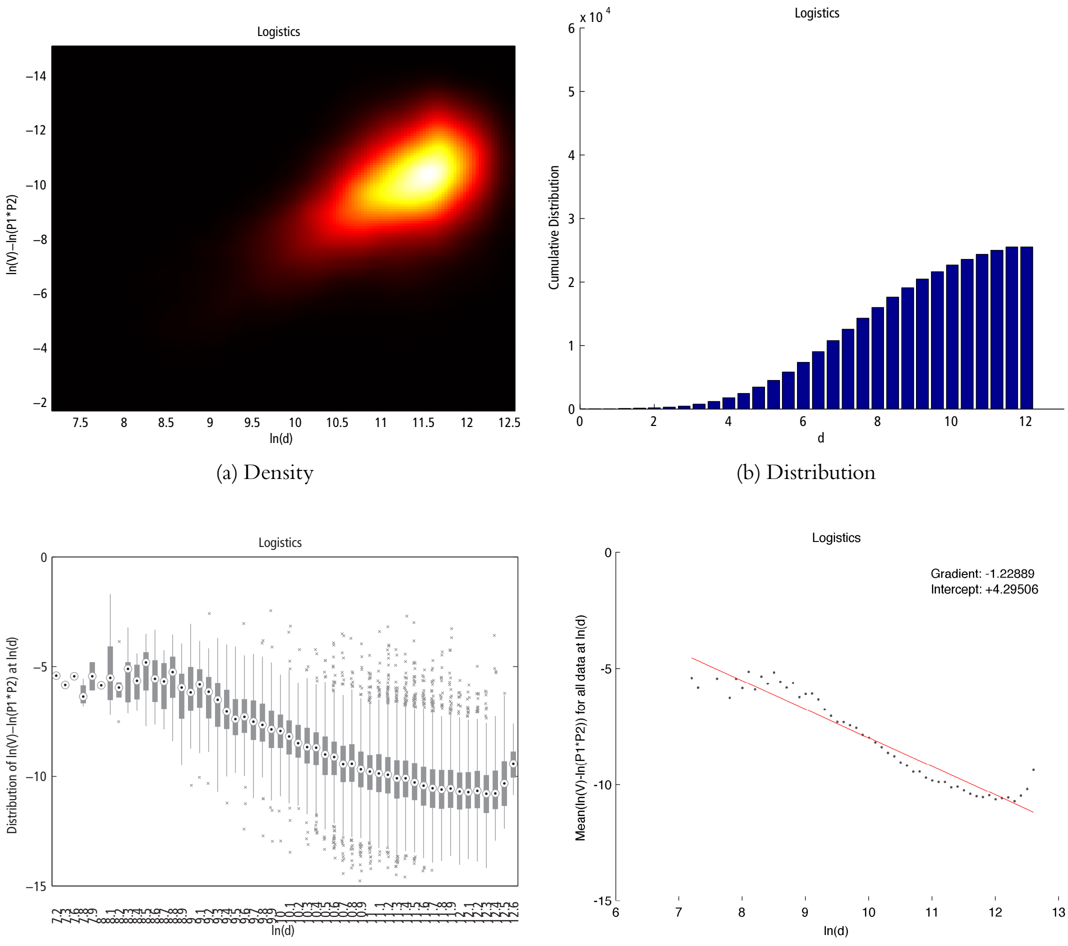
(a) Density

(b) Distribution

(c) Boxplot

(d) Fitted

Figure 11.46: ICT Distance Decay



(a) Density

(b) Distribution

(c) Boxplot

(d) Fitted

Figure 11.47: Logistics Distance Decay

12
Appendix D: Data Management & Processing

12.1 Further Details on CLLIs

All Common Language Location Identifiers (CLLIs) are mappable on to a set of spatial coordinates and the code can usually be broken down into four logical groupings: a four-letter city code (*e.g.* NYCM for New York City, Manhattan), a two-letter state or provincial code (*e.g.* NY for New York or NB for New Brunswick), a two-character site code (the facility where the equipment is located), and a three-character network-entity code specifying the actual piece of hardware or infrastructure. Four examples of valid CLLIs are provided below in Table 12.1, and readers wishing to further explore this type of data can use Telcordia's web site and CLLI lookup page (Telcodata, 2009a).

City Code	State/Province Code	Network Site Code	Network-Entity Code	Description
NYCM	NY	79	DS0	A digital switch (possibly the only one) at site 79 in New York City (Manhattan)
NYCK	NY	14	DS0	A digital switch (possibly the only one) at site 14 in King's County (Brooklyn)
CCGN	NB	SC	RS0	An analogue switch (possibly the only one) in Cocagne, New Brunswick
WAHW	HI	MN	DS1	A digital switch (the second of two or more) in Wahiawa, Hawaii

Table 12.1: Sample Eleven Character CLLI Codes

The CLLI should not be confused with the Numbering Plan Area (NPA) and Exchange Code/Central Office (NXX) specification. The NPA is rather better-known as an area code, and in the case of North American numbers it is always the first three digits of a valid phone number; the next three digits specify the NXX and would once have identified a sub-region within the NPA. A single CLLI can be responsible for several NPA/NXX blocks: the Telcordia page for the Brooklyn CLLI NYCKNYFTDS0 shows that it covers 718–283, 718–431, 718–435, 718–436, and ten more 718-based exchanges (Telcodata, 2009b).

Readers familiar with the North American schema will be aware that number portability (the ability to transfer a number anywhere in the country) and mobility (the fact that there is no numeric distinction between fixed and mobile numbers) mean that the NPA/NXX of any arbitrarily-selected number no longer tells us much about its actual location, and so calls to a given CLLI do not necessarily terminate here, but may be re-routed to a different location entirely.

12.2 Further Details on Wire Centres & Exchanges

Unlike European operators, who have tended to operate fixed and mobile infrastructure using separate numbering, routing, and billing systems, American operators have typically supplied both types of service to customers on the same basis. The lack of an embedded distinction between fixed-line and mobile numbers means that the two types of data are intermingled, along with private branch exchange (PBX) traffic for businesses or buildings that house their own switching equipment. This means that there is *no* straightforward way to determine that, say, NYCKNYFTDS0 handles fixed-line data while NYCKNYFTDS1 handles mobile traffic.

	Manhattan	Queens	Brooklyn	The Bronx	Staten Island	All Wire Centres
Material Suppressed						

Table 12.2: Wire Centre Averages by Borough

Compared to the North American system, the British system is markedly simpler to understand even if it is no less logistically and technically complex. In the first place, because British mobile numbers use a distinct, non-geographical numbering schema they are easy to pick out and exclude from the spatial analysis, obviating the need for the more challenging CLLI-to-NPA mapping process employed in North America. Furthermore, landline numbers in Britain are not portable, which means that they can only be transferred between outlets or buildings within a more modest geographical area. A more detailed technical explanation of how the British network functions is available from Feather (2000).

	London UA	GSE	England
Resident Population	7,270,525	21,410,906	50,451,657
Material Suppressed			
Working Population	3,987,780	9,849,160	N/A

Table 12.3: Overview of Analysis Subregions by PXA

12.3 Data Management

Overview

The American telecommunications company supplied a high-level view of telecoms traffic on its network, including data indicating the platform—wireless, wireline, dedicated, VOIP, and pre-paid calling card—used to place the call and the 'direction'—originating or terminating in New York City—of the call. For privacy reasons, the records do not uniquely identify customers or phone numbers and simply provide a total count of calls and minutes to unique destinations worldwide. This level of aggregation and privacy is theoretically ideal for this type of research but for one thing: a single CLLI may service an area containing thousands of individuals and dozens of firms. In a one-hour period, the heaviest volume of CLLI traffic observed in the data set exceeded 125,000 calls, and with such massive volumes it is impossible to untangle overlapping users of telecommunication services such as business and residential customers.

The U.K.-based operator supplied a more fine-grained view of calling activity, including information on call duration in addition to the more usual platform details and high-level location. In this case, the carrier had performed much of the cleaning, canonicalising, and aggregating on its own servers, so what was delivered was essentially a 'live' copy of a pre-screened database which could be simply be copied directly into the data warehouse. Given the size of this second database (≈ 1TB), the slightly different approach was a valuable time and space saver since the next three stages detailed below could be bypassed completely. However, regardless of the differences in process, the end result outlined in the Entity-Relationship Diagram below (see Figure 12.3 on page 481) was the same.

Record Layout & Coverage

The American telecommunications company supplied data from its New York area voice and data operations for the entire month of September 2008. Raw log files were cleaned and aggregated; in all, more than 10GB of plain-text data were processed, but after aggregating the data temporally and spatially using several different resolutions this became a rather more manageable.

Table 12.4: Record Layout for American Calling Data

Field Name	Sample Value	Description
Date	20080901	Date of observation in format yyyymmdd
Time	100000	Time of observation in format h[hmmss]
Type	WIRELINE	Type of call: Wireless, Wireline, Dedicated, Pre-Paid Calling Card, VOIP
Direction	TERM	Originating or Terminating in New York
NYC CLLI	NYCMNY36DS1	Location within New York City
Latitude	40.XXXXXX	NYC CLLI Latitude (to 6 decimal places)
Longitude	-72.XXXXXX	NYC CLLI Longitude (to 6 decimal places)
Borough	Brooklyn	NYC CLLI Borough
Counterparty	CHCGILFRDS0	Where applicable, the CLLI of the counter-party
Country	US	Counter-party's ISO 2-character country code
State	IL	Counter-party's ISO 2-character state code
Area	Chicago	Counter-party's area name (where available)
Calls	5	Number of new calls in previous hour
Minutes	27.356667	Time spent on all calls in previous hour

A sample, formatted for easier reading, is provided to illustrate the contents of the raw comma-delimited data files (latitude and longitude coordinates have been edited for security reasons):

```
20080901,0,DEDICATED,TERM,NYCXNYTRXXX,40.XXXXXX,-72.XXXXXX,
               Bronx,APNUNK,US,No_state,,1,1.550000
20080901,0,PPC,ORIG,NYCKNYARXXX,40.XXXXXX,-72.XXXXXX,
               Brooklyn,7,RU,Non_us_state,,1,7.133333
20080901,0,PPC,ORIG,NYCKNYCLXXX,40.XXXXXX,-72.XXXXXX,
               Brooklyn,BEVLSCMAXXX,US,SC,BENNETTSVL,1,9.966667
20080901,0,PPC,ORIG,NYCMNY36XXX,40.XXXXXX,-72.XXXXXX,
               Manhattan,WBYNNYAKXXX,US,NY,UNKNOWN,1,0.416667
20080901,0,PPC,ORIG,NYCMNY37XXX,40.XXXXXX,-72.XXXXXX,
               Manhattan,BRSBCABEXXX,US,CA,SNFC CNTRL,2,0.333333
20080901,0,PPC,ORIG,NYCNNYFUXXX,40.XXXXXX,-73.XXXXXX,
               Manhattan,PLTNCAAYCM1,US,CA,SAN RAFAEL,6,21.150000
20080901,0,VOIP,ORIG,NYCQNYCOXXX,40.XXXXXX,-72.XXXXXX,
               Queens,9144,IN,Non_us_state,Chennai (Madras) ,1,0.000000
```

Cleaning

During the cleaning phase records and fields are scanned for irregularities or errors and, if circumstances warrant, rejected entirely or flagged for review by the human operator. Work by the American telecommunications company ensured that relatively few problem records were identified, but some minor issues (*e.g.* standardising city names and values for 'missing' fields) were addressed in this phase.

Canonicalising

In canonicalization we convert the raw records into a canonical form—in this case the unique, numeric database identifiers that will enable us to more easily sort and aggregate the data. This also has the significant advantage of reducing the working file size substantially. The basic process involves taking each reference field (*e.g.* a CLLI or a non-U.S. location) and creating a new database key for values that are complete new, or retrieving an existing key for values that have been encountered previously.

Processing of the city field for counterparties required a good deal more flexibility with one-off matches and pattern-based substitutions. Since we could not know what portion or portions of the city name had been 'mangled' by the data collection process, I designed a recursive process that sought to find the simplest and shortest possible match with a publicly-available 'gazetteer' (*i.e.* list of places). For instance, in the case of a raw city name of 'HTSLPHRSPG' the gazetteer search would operate as follows:

- `HTSLPHRSPG`
- `HTSLPHRSPG*`
- `HTSLPHRSP*G*`
- …
- `H*T*S*L*P*H*R*S*P*G*`

If there were no match on this last search, then the application attempts to make some logical guesses based around common abbreviations. While time-consuming, because application contained a method for downloading a caching the results for a country or countries we could still perform thousands of searches per second. For places that did *not* match the gazetteer, it is also possible to look for simple abbreviations (*e.g.* 'vl' for 'ville', and 'ft' for 'fort'); naturally, this challenge extended to multilingual issues as well (*e.g.* 'riv' for 'riviére') and to issues with overloaded identifiers (*e.g.* 'ILE6DE6FRANCE' for, seemingly, 'Île-de-France #6').

Storage

The cleaned, canonicalised, and sorted data file can then be loaded into a data warehouse. Although this process can be slow for large numbers of records it is nonetheless fairly straightforward. Both databases follow a loose snowflake schema (Wikipedia, 2005c), meaning that there are two broad classes of tables: facts and dimensions. Dimensions and fact tables can be understood by reference to a practical example: a phone number is unique in the entire data set and is thus a *dimension* of the data we're studying, while the calls made by that phone number are observed *facts*. Similarly, exchanges, area codes, dates, times and calling types are all dimensions, while monthly, weekly, and hourly levels of aggregation, and summary statistics related to the number of the calls are all facts.

Each logical entity—dates, CLLIs, domestic and international counterparties, and calling platforms—was stored in its own dimension table and then further normalised as needed to increase query performance and search-ability. Calls were stored at several levels of temporal aggregation: hourly, weekly, by day of week, and monthly. This approach enables the data to be quickly and flexibly interrogated at the appropriate level of detail and for the results to be easily checked back against the raw data.

The snowflake design means that few, if any joins between Fact and Dimension tables are required during aggregation. Consequently, the process can be performed directly within the database without the need for more complex distributed systems such as BigTable or MapReduce. In effect, we can do sorting, matching, and grouping directly within the SQL query and without having to perform any kind of table join in order to link the fact table to the location tables.

Aggregation

By grouping the data in different ways we can compress billions of records of raw hourly data by 50% or more. The aggregate tables help with the analysis in different ways: we can quickly scan the entire data set to build a 'feel' for the data and to identify patterns (*e.g.* specific destinations) with particularly high or low incidences; we can then examine how calls to or from particular destinations vary by the day of the week; and, finally, we can look at hour-by-hour changes in calling patterns across an entire week. On a system with 32GB of RAM and 10TB of disk space it was possible to perform all aggregation tasks on the smaller of the two data sets in less than 12 hours, while on the largest table in the larger data set aggregation took approximately 1.5 days to complete.

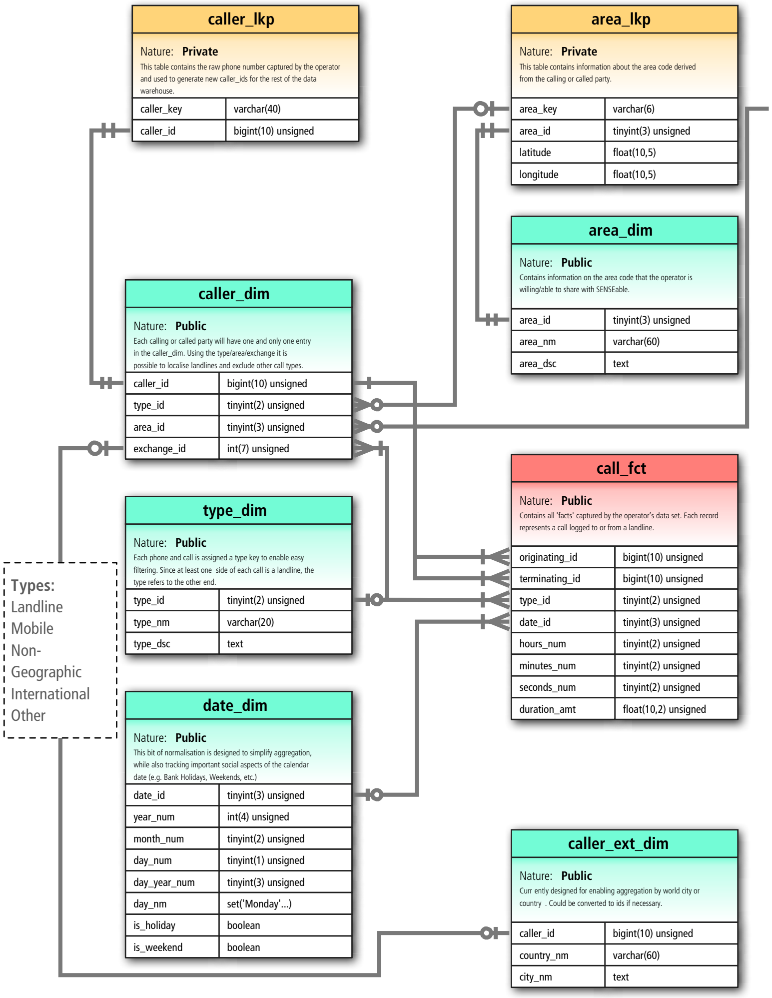


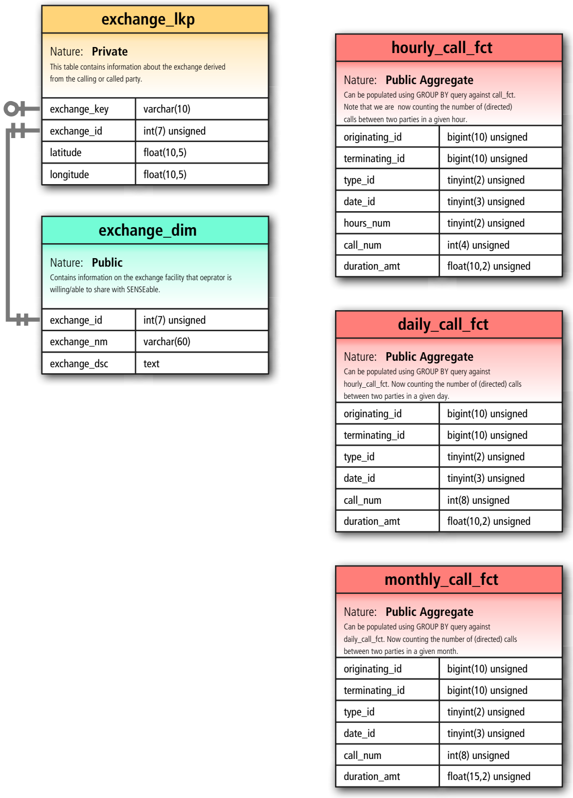
Figure 12.1: Part 1 of Entity Relation Diagram

12.4 *Matlab Analysis*

In computer science, heuristic applications imply not only a trial-and-error approach to problem-solving, but also a form of machine learning which "utilize[s] self-educating techniques (as the evaluation of feedback) to improve performance" (Merriam-Webster Online Dictionary, 2009). Both of these definitions are applicable to the approach employed in this research—not only was a trial-and-error approach developed in response to an evolving understanding of the data and its constraints, but the ultimate solution involved the application of automated learning algorithms, and in particular unsupervised clustering techniques, to generate meaningful results.

In that sense, the SENSEable eigenplace toolkit falls squarely within both CSS and heuristic approaches to knowledge discovery in databases (KDD). I also felt that it would be helpful to illustrate the user-side view of the analytical process using screen-shots taken while the process was

Figure 12.2: Part 2 of Entity Relation Diagram



running to demonstrate the potential for this type of methodology. Particular attention should be given to the way that this approach allows a user with only modest technical and scientific knowledge to execute the basic code and explore various clustering alternatives in an interactive manner.

The geography and input data to be used in the analysis are specified in a configuration file that is designed to be read and updated by users with only modest knowledge of the underlying processes involved in generating eigenplace clusterings. In Figure 12.3, the analytical geography has been set to 'Great Britain' (*i. e.* 'GB'), and the data will be doubly-normalised by both the number of phones in each PXA as well as by the natural log of the resulting per-PXA calls and minutes. It is also possible to normalise by the population of the PXA, though this would only work for the finer geographic scales: the Greater South East of England (GSE), the Outer Metropolitan Area (OMA), and London (LDN).

Figure 12.3 also shows that it is possible to retain information about

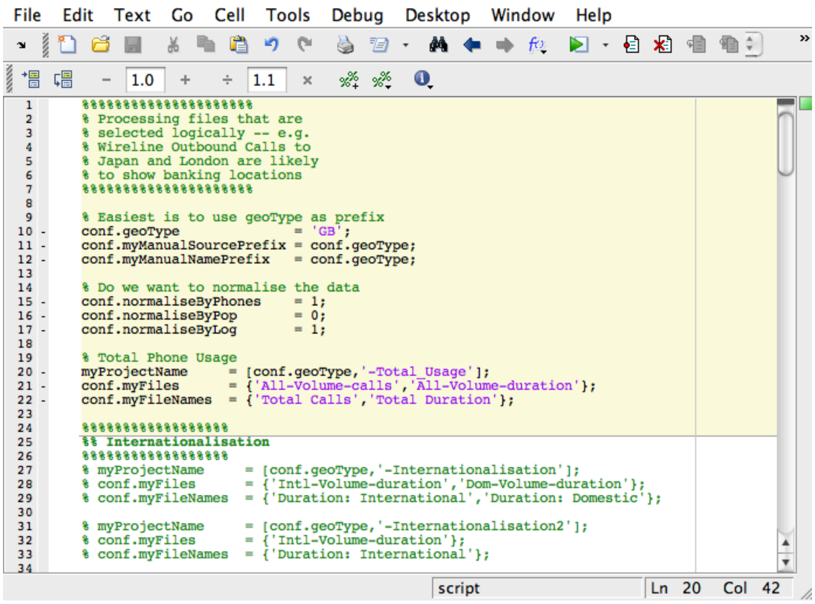


Figure 12.3: Configuration File

previous sessions/projects that have been run, simply by commenting and uncommenting code. Using a unique project name (typically formed from the compound of the geographic scale and some user-specified value) it is possible to quickly reload data at various stages of processing (see Figure 12.4) and continue an analysis or try re-running a previous analysis with slightly different parameters. The input parameter 'myFiles' specifies the raw file names to be used in the analysis, and 'myFileNames' allows the user to specify a friendlier label to be used on charts and figures. In a future revision to the codebase it would obviously be helpful to move the specification of inputs and normalisation to a Graphical User Interface (GUI), but this was not a priority for this work.

Once the inputs have been specified, the rest of the user's work takes place within a GUI, and Figure 12.4 presents the main processing window in which the principal stages of the eigenplace computation are shown. In 'General' the user is able to specify the sampling step of the Discrete Fourier Transform together with the number of days of data contained in the input file (currently this only supports values of 1 and 7). The 'Sampling step' value corresponds to the shortest period for which meaningful frequencies have been found in previous telecoms research.

The 'Features' section of the Main Window shown in Figure 12.4 is where the unsupervised feature selection algorithm developed by Mitra et al. (2002) is implemented. The maximum temporal frequency used for the Discrete Fourier Transform and the eigendecomposition operations can be specified, as can the number of features (or a percentage of the total number of features) to be selected. For large geographies, calculating all features can take several minutes, but the process has proved to be highly robust and scalable. Feature selection itself is quite quick, taking less than 15 seconds for even very large geographies.

Once the desired number of features has been selected, the is able

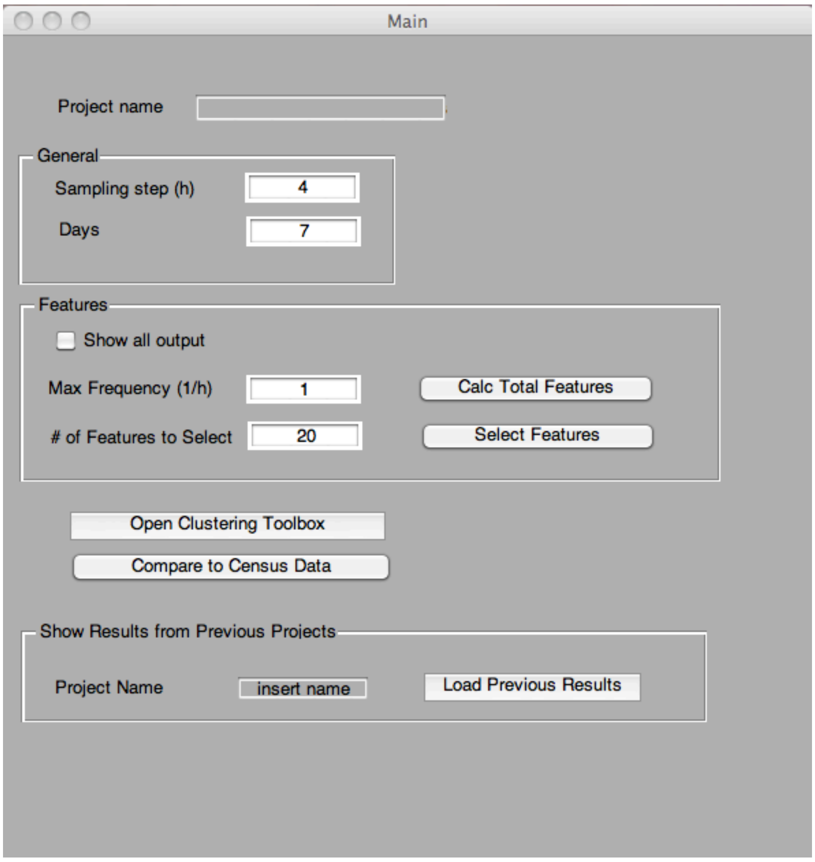


Figure 12.4: Main Window

to open a new 'Clustering Window' (see Figure 12.5) in which several clustering options have been implemented. At this time only the *k*-Means algorithm has been fully-implemented for customisable geographies, but in subsequent work I hope to update the codebase to incorporate Fuzzy *c*-/*k*-Means clustering, and other approaches to clustering the data. Note that the maximum number of clusterings to generate and test is user-specifiable and that the user can also easily try a different clustering if the results prove inconclusive.

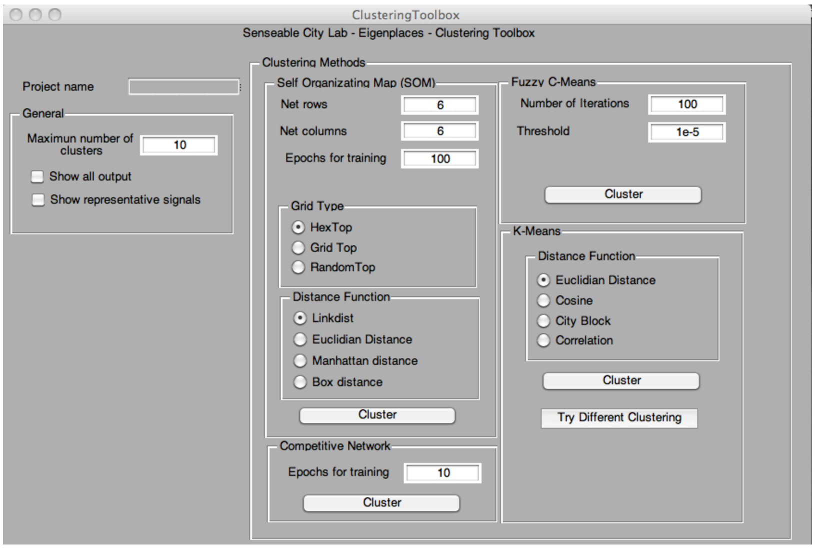


Figure 12.5: Clustering Window

List of Abbreviations

Table 12.5: List of Abbreviations

Abbreviation	Details
APS	Advanced Producer Services
ATM	Automated Teller Machine
BBC	British Broadcasting Corporation
BSC	Base Station Controller
BPS	Business Services Provider
BSU	Basic Spatial Unit
CBD	Central Business District
CDO	Collateralised Debt Obligation
CLLI	Common Language Location Identifier
DNS	Domain Name System
DSL	Digital Subscriber Line
DVD	Digital Versatile Disk
EDI	Electronic Data Interchange
ETL	Extract, Transform & Load
FIRE	Finance, Insurance & Real Estate
FX	Foreign Exchange
GIS	Geographic Information System
GPRS	General Packet Radio System
GPS	Global Positioning System
GSE	Greater South East of England
GUI	Graphical User Interface
GVA	Gross Value-Added
HR	Human Resources
HSR	High-Speed Rail
ICT	Information & Communications Technology
IP	Internet Protocol; Intellectual Property
ISO	International Standards Organisation
ITS	Intelligent Transportation Systems
JIT	Just In Time
KIBS	Knowledge-Intensive Business Services
LQ	Location Quotient

Abbreviation	Details
MNE	Multi-National Enterprise
NESTA	National Endowment for Science, Technology & the Arts
NOMIS	National Online Manpower Information System
NGO	Non-Governmental Organisation
NPA	Number Plan Area
NSA	National Security Affairs
NXX	Exchange Code/Central Office
NYC	New York City
OECD	Organisation for Economic Cooperation & Development
OMA	Outer Metropolitan Area of London
PXA	Public Exchange Area
RFP	Request For Proposals
ROI	Return-On-Investment
SEE	South East of England
SLQ	Standardised Location Quotient
SNCF	Société National des Chemins de Fer
SME	Small or Medium Enterprise
SMS	Short Messaging Service
TGV	Train Grand Vitesse
TPM	Technical Project Manager
TQ	Telecommunications Quotient
UA	Urban Audit Area
URL	Uniform Resource Locator
UPS	United Parcel Service; Uninterruptible Power Supply
VC	Venture Capital Firm/Venture Capitalist
VoIP	Voice Over IP

Standard Industrial Classification

Table 12.6: Alphabetical Standard Industrial Classification Codes

SIC Code	Details
A, B	Agriculture and fishing
C, E	Energy and Water
D	Manufacturing
F	Construction
G, H	Distribution, hotels and restaurants
I	Transport and communications
J, K	Banking, finance and insurance, real estate
L, M, N	Public administration, education, health
O, P, Q	Other services

Table 12.7: 3-Digit Standard Industrial Classification Codes

SIC Code	Details
602	Other land transport
622	Non-scheduled air transport
631	Cargo handling and storage
651	Monetary intermediation
652	Other financial intermediation
660	Insurance and pension funding, except compulsory social security
671	Activities auxiliary to financial intermediation, except insurance and pension funding
672	Activities auxiliary to insurance and pension funding
701	Real estate activities with own property
721	Hardware consultancy
722	Software consultancy and supply
723	Data processing
724	Data base activities
731	Research and experimental development on natural sciences and engineering
741	Legal, accounting, book-keeping and auditing activities; tax consultancy; market research and public opinion polling; business and management consultancy; holdings
742	Architectural and engineering activities and related technical consultancy
744	Advertising
921	Motion picture and video activities
922	Radio and television activities
925	Library, archives, museums and other cultural activities

Table 12.8: 4-Digit Standard Industrial Classification Codes

SIC Code	Details
6010	Transport via railways
6024	Freight transport by road
6110	Sea and coastal water transport
6120	Inland water transport
6210	Scheduled air transport
6220	Non-scheduled air transport
6311	Cargo handling
6312	Storage and warehousing
6321	Other support land transport activities
6322	Other support water transport activities
6323	Other support air transport activities
6511	Central banking
6512	Other monetary intermediation
6521	Financial leasing
6522	Other credit granting
6523	Other financial intermediation not elsewhere classified
6601	Life insurance
6603	Non-life insurance
6711	Administration of financial markets
6712	Security broking and fund management
6713	Activities auxiliary to financial intermediation not elsewhere classified
6720	Activities auxiliary to insurance and pension funding

SIC Code	Details
7011	Developing and selling of real estate
7012	Buying and selling of own real estate
7020	Letting of own property
7031	Real estate agencies
7032	Management of real estate on a fee or contract basis
7210	Hardware consultancy
7221	Publishing of software
7222	Other software consultancy and supply
7230	Data processing
7240	Data base activities
7250	Maintenance and repair of office, accounting and computing machinery
7260	Other computer related activities
7310	Research and experimental development on natural sciences and engineering
7320	Research and experimental development on social sciences and humanities
7411	Legal activities
7412	Accounting, book-keeping and auditing activities; tax consultancy
7413	Market research and public opinion polling
7414	Business and management consultancy activities
7415	Management activities of holding companies
7420	Architectural and engineering activities and related technical consultancy
7440	Advertising
7481	Photographic activities
7486	Call centre activities
7487	Other business activities not elsewhere classified
9211	Motion picture and video production
9212	Motion picture and video distribution
9213	Motion picture projection
9220	Radio and television activities
9231	Artistic and literary creation and interpretation
9232	Operation of arts facilities
9234	Other entertainment activities not elsewhere classified

Group/SIC Code	Description	London	GSE
Total Employment	All sectors	**3,987,780**	**9,849,160**
SIC 631	Cargo handling and storage	10,217	43,054
SIC 651	Monetary intermediation	131,735	202,475
SIC 652	Other financial intermediation	42,484	66,037
SIC 660	Insurance and pension funding, except compulsory social security	29,912	80,529
SIC 671	Activities auxiliary to financial intermediation, except insurance and pension funding	73,845	94,179
SIC 672	Activities auxiliary to insurance and pension funding	36,132	69,832
SIC 721	Hardware consultancy	3,603	12,278
SIC 722	Software consultancy and supply	66,357	182,957
SIC 724	Data base activities	3,868	7,549
SIC 731	Research and experimental development on natural sciences and engineering	13,293	60,617
SIC 741	Legal, accounting, book-keeping and auditing activities; tax consultancy; market research and public opinion polling; business and management consultancy; holdings	276,099	494,728
SIC 742	Architectural and engineering activities and related technical consultancy	57,682	140,272
SIC 744	Advertising	31,831	53,215
SIC 921	Motion picture and video activities	18,750	26,335
SIC 922	Radio and television activities	37,282	42,985
SIC 925	Library, archives, museums and other cultural activities	16,808	35,122

Table 12.9: Selected Sectoral Breakdown of Employment in London and the GSE

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